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ARCHIVES OF SURGERY

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THE BACTERIOLOGY OF ABSCESS OF THE LUNG AND METHODS FOR ITS STUDY *

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NEW YORK

There is a great deal of disagreement in the literature as to the presence or absence of anaerobes in the fetid pus of suppurations from the lung. In 1893, Veillon examined the bacteriology of fetid pus and first pointed out the rôle of anaerobes in these cases. In 1898, Veillon and Zuber [1] studied systematically the diseases characterized by gangrene; they isolated a number of anaerobic organisms and concluded that this process is elicited by them. This was confirmed by Hallé,[2] Rist [3] and Cottet.[4] Guillemot [5] later applied the technic of Veillon and Zuber in the study of pus from pulmonary suppurations. He found *Bacillus ramosus* in eight of thirteen cases, *B. fragilis* in six, *Micrococcus foetidus* in three, *B. thetoides* in three, *B. fusiformis* in two and *Staphylococcus parvulus* in one. He ascribed to *B. ramosus* an important rôle in the pathogenicity of abscess of the lung when it is associated with another organism, such as the streptococcus.

Since 1898, a great deal of discussion has arisen in the literature as to whether anaerobes are actually found in suppurations of the lung. In fact, their presence in cases of abscess of the lung was entirely ignored in the later literature on the subject, probably because of the difficulty of their isolation. While it is true that fusiform bacilli and spirochetes were isolated by Smith [6] and noted by other observers on

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* From the Laboratories of Mount Sinai Hospital and from the Surgical Service of Dr. Harold Neuhof.

1. Veillon and Zuber: Recherches sur quelques microbes strictement anaerobiés et leur rôle en pathologie, Arch. de méd. expér. d'anat. path., July, 1898.

2. Hallé: Recherches sur la bacteriologie du canal génital de la femme, Thèse de Paris, 1898.

3. Rist: Anaerob pathogens et suppurative gangreneuse, Bull. Inst. Pasteur **3**:49, 1905.

4. Cottet: Recherches bacteriologique sur les suppurative péri-urethrales, Thèse de Paris, 1899.

5. Guillemot: Recherches sur la gangrène pulmonaire, Thèses de la Faculté de Médecine, 1898.

6. Smith, D. T.: Fuso-Spirochaetal Disease of the Lungs, Am. Rev. Tuberc. **16**:584, 1927.

direct spreads of pus (Kline,[7] Pilot and Davis,[8] Arnheim,[9] Bezançon,[10] Farah,[11] Castellani,[12] Nolf,[13] Seguin and Kritchewsky,[14] Fishberg and Kline,[15] Buday[16] and Bykowa[17]), the organisms described by Guillemot[5] (i. e., *B. ramosus, B. fragilis, M. foetidus, B. thetoidis, B. fusiformis* and *Staph. parvulus*) were not found or were lost sight of entirely. Hartwell[18] found *Staphylococcus aureus* the predominating organism in abscess of the lung as recently as 1920. He concluded that *Staphylococcus aureus* was an important agent in the formation of abscesses. Lyman[19] believed that no special organism can be held accountable. In 1924, Lambert and Miller,[20] studying the bacteriology of abscess of the lung, found various anaerobes which they designated as gram-positive bacilli, gram-negative bacilli, cocci and streptothrix. They did not report cultures, nor did they attempt a systematic bacteriologic study. They concluded that the striking feature of abscess of the lung was that only anaerobes were found. On the other hand, Ermatinger[21] insisted that hemolytic *Staphylococcus aureus* is the pyogenic organism most frequently encountered. He found it in 80.75 per cent of cases. The hemolytic streptococcus was found in the others. Bucher,[22] also, concluded that the streptococcus was the organism found in 79 per cent of cases studied. Of the organisms found, those next in importance were *Staphylococcus aureus* and *albus*. More recently,

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7. Kline, B. S.: Experimental Gangrene, J. Infect. Dis. **32**:481, 1923.

8. Pilot, I., and Davis, D. J.: Studies in Fusiform Bacilli and Spirochetes, Arch. Int. Med. **34**:313 (Sept.) 1924.

9. Arnheim: Die Spirochäten bei Lungengangrän und ulzierenden Carcinom (Kultur-Versuche), Centralbl. f. Bakt. **59**:20, 1911.

10. Bezançon, F., and Etchegoir, E.: Spirochaeta bronchialis et gangrène pulmonaire, Compt. rend. Soc. de biol. **94**:319, 1926.

11. Farah: Spirochetose bronchique, Presse méd. **27**:774, 1919.

12. Castellani: Bronchial Spirochetosis, Brit. M. J. **2**:782, 1909.

13. Nolf, P.: Fetid Spirillar Bronchitis and Pulmonary Gangrene, Arch. Int. Med. **25**:429 (April) 1920.

14. Seguin and Kritchewsky: Spirochetose buccales, Rev. de stomatol., 1920-1922, p. 613.

15. Fishberg, M., and Kline, B. S.: Spirochetal Pulmonary Gangrene, Arch. Int. Med. **27**:61 (Jan.) 1921.

16. Buday: Histologische Untersuchungen über die Entstehungsweise der Lungengangrän, Beitr. z. path. Anat. u. z. allg. Path. **48**:70, 1910.

17. Bykowa, O.: Zur Ätiologie der Lungengangrän, Virchows Arch. f. path. Anat. **258**:617, 1925.

18. Hartwell, J. A.: Abscess of the Lung, Ann. Surg. **72**:333, 1920.

19. Lyman, H. W.: Abscess of the Lung, South. M. J. **15**:744, 1922.

20. Lambert, A. V. S., and Miller, J. A.: Abscess of the Lung, Arch. Surg. **8**:446 (Jan.) 1924.

21. Ermatinger, L. H.: Microorganisms of Lung Abscess and Bronchiectasis, J. Infect. Dis. **43**:390, 1928.

22. Bucher, C. J.: Abscess of the Lung, Am. J. M. Sc. **174**:406, 1930.

Varney [23] described an anaerobic organism, *B. melaninogenicum*, in abscess of the lung. He believed that this organism played a significant rôle in its production.

As is seen, some observers ascribe prominence to *B. fusiformis* and to spirochetes, others to pyogenic organisms alone, while Varney attached an important rôle to *B. melaninogenicum*. In view of the confusion in the literature on the subject, the importance of a thorough study of the bacteriology of this disease entity is evident. While anaerobes are noted in certain instances, their isolation either is not attempted or is impossible because of lack of proper technic and apparatus. While the pus taken at operation may show various cocci, gram-positive and gram-negative bacilli, fusiform bacilli and spirochetes, even after twenty-four hours few of these organisms are found in cultures. Some observers, notably Varney and Smith, though able to isolate certain of these organisms, fail to isolate others.

The work reported in this paper was done in order to study culturally the entire bacterial flora of abscess of the lung. In a problem of this scope, it was thought desirable and important first to attack it from the point of view of the methods already available, and if these were found wanting to devise a simple and practicable procedure for the cultivation of the anaerobic flora in suppurations of the lung. To define the premise on which the conception of a strict anaerobe should rest was the next task.

STUDIES ON CONDITIONS FOR ANAEROBIC GROWTH

Mediums.—The Smith-Noguchi Medium: This medium was prepared from ascitic fluid to which 1 per cent of dextrose and 1 per cent of peptone broth were added. Ten cubic centimeters of this fluid was poured into a long, narrow test tube, 20 by 1.5 cm., which contained a piece of fresh sterile rabbit's kidney. This was incubated overnight for sterility.

Blood Plates: To 5 cc. of citrated blood was added 95 cc. of plain agar with a p_H of 7.4, melted in the Arnold steam sterilizer and cooled to 45 C.; the mixture was then poured into plates.

Ascitic Fluid Agar: Sixty-five cubic centimeters of ascitic fluid with a p_H of 7, was added to 150 cc. of 2 per cent dextrose agar, with a p_H of 7.8, at 50 C., and plates were poured from this mixture.

Sugar Mediums: The sugar mediums used were prepared in accordance with the directions given by Murray.[24]

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23. Varney, P. L.: Bacterial Flora of Treated and Untreated Abscesses of the Lung, Arch. Surg. **19**:1609 (Dec.) 1929.

24. Murray: Sugar Media for Meningococci, Medical Research Council, publication no. 124, London, His Majesty's Stationery Office, 1929.

Gelatin and Litmus Milk: In order to make it possible for strict anaerobes to grow in gelatin or in litmus milk, a piece of rabbit's kidney was added.

All fluid mediums were covered with petrolatum seal before incubation.

Methods of Anaerobiosis.—Method of Surface Culture: In pus containing from four to ten different organisms, the most feasible method of isolation is by the surface growth of individual colonies. This offers an opportunity for the study of their cultural characteristics and their morphology.

Various factors that were likely to influence the growth of anaerobic organisms on the surface of plates were studied as follows:

(*a*) Time of exposure to air: The time elapsing between the moment of inoculating the plates, the final disposition in the jar and the production of anaerobiosis is undoubtedly of great importance. At best, from thirty minutes to an hour can be counted as the minimum, at which time the exposure to aerobic conditions injures the anaerobic organisms. Barber [25] pointed out that some strict anaerobes may be destroyed even by exposure of less than an hour to atmospheric oxygen.

(*b*) Moisture inside the anaerobic jar: The growth of delicate anaerobic organisms on the surface of plates requires more moisture than does the growth of aerobic organisms. One method of supplying moisture to the plates is by making the jar moist.

(*c*) Effect of pus on the growth of anaerobes: Studies on the conditions of anaerobic cultivation of the anaerobic flora of abscess of the lung suggested the fact that the pus in which the organisms originated promotes their growth on the surface. That this factor is efficacious in influencing their growth also under aerobic conditions is shown in the following statement: When thick sticky pus containing anaerobic organisms is spread on a blood plate and incubated aerobically, the part of the plate where the pus is thickest will show the survival of some of the anaerobic organisms.

In this connection it is interesting to note that Shearer [26] observed the favorable effect of the accessory factors of growth contained in the nasal secretion and in the spinal fluid on the growth of meningococci.

For these reasons a routine procedure was adopted of centrifugating every twelve to twenty-four hour fresh culture in Smith-Noguchi medium; the supernatant fluid was discarded, and the pussy sediment was used for inoculating the plates.

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25. Barber, M. A.: Use of Single Cell Method in Obtaining Pure Cultures of Anaerobes, J. Exper. Med. **32**:295, 1920.

26. Shearer, G.: On the Presence of Accessory Food Factors in the Nasal Secretions, Lancet **1**:59, 1917; On the Action of Spinal Fluid, ibid. **2**:714, 1917.

(*d*) Effect of gum arabic: A growth-promoting effect was also observed when gum arabic instead of pus was used on the surface of the plates. The following method was employed:

One cubic centimeter of sterile 10 per cent solution of gum arabic in peptone broth with a p_H 7.4 is spread over a blood plate One drop of a twenty-four hour culture of a strict anaerobe—*Staph. putridus* (obtained through the courtesy of Dr. Schottmüller)—is mixed with the gum arabic-bouillon solution. This plate is incubated aerobically. A drop of the same twenty-four culture is spread on another blood plate, and is also incubated aerobically. Within from twenty-four to forty-eight hours, the blood plate containing the gum arabic will show a scant growth of the strictly anaerobic organism. The second blood plate, inoculated with the culture alone, will not show a growth.

(*e*) Influence of pressure exerted on the plate by the inoculating needle: Finally, the most important factor responsible for the growth of anaerobic organisms on the surface of plates is the pressure with which the inoculating needle submerges the organism just under the surface of the agar. Thus, if a drop of pus is spread on the surface of a blood plate with an ordinary platinum wire, no growth of the strict anaerobes will result. If, on the other hand, a heavy platinum wire is used and firm pressure is applied, growth of individual colonies will result. Varney,[27] using the principle of pressure, devised a revolving stand with a stationary inoculating needle. He called it the spiral streak plate method. The plate to be inoculated is placed on the stand and is revolved about the needle in a spiral fashion until the whole surface of the plate is covered. The reasons for the beneficial effect of pressure on the growth of anaerobes on the surface may be due to various factors: (1) by the additional pressure, the bacteria adhere better to the surface; (2) the high viscosity of pus requires greater pressure for the separation of the bacteria and (3) the tiny burrows of grooves in the agar mediums give the organisms additional anaerobic protection.

The Inoculating Brush.—A brush was designed in this laboratory which embodies the advantages of pressure and also, by the use of a number of inoculating points instead of the one ordinarily used, increases the opportunities for the isolation of rare organisms. Moreover, it has additional advantages in that it is economical to make in the laboratory and is convenient and easy to handle; the whole plate can be covered completely in much less time than it ordinarly takes to inoculate with a single platinum wire.

The brush consists of from fifteen to twenty strands of aluminum wire no. 8, about from 12 to 15 cm. in length. These strands are bound together and bent into the shape of a brush (fig. 1). Another strand

27. Varney, P. L.: A New Spiral Streak Plate Method of Isolating Bacteria by Means of Inoculating Machine, J. Infect. Dis. **41**:190, 1927.

of wire is wound around the handle. A brass clip (fig. 1 *b*) is fastened near the neck (fig. 1 *a*), which keeps the teeth of the brush separated. A number of such brushes can be made in a short time. They are boiled in soap and water, rinsed thoroughly in running water, dried and then sterilized in a metal container by dry heat for one hour. When ready for use, each brush is lifted out of the container with a pair of sterile forceps.

In inoculating plates, a drop of pus is placed at the periphery; the teeth of the brush are then thoroughly mixed with it, and parallel streaks are made. Cross-streaks perpendicular to these are also made. The plate finally appears like a ground work mosaic (fig. 2). Motion with the brush should be firm and steady, care being taken not to force the wire through the agar. The colonies of the different organisms will appear at the side of the streak, or will overgrow the grooved depressions. Thus they can be picked up under the microscope and seeded into fresh Smith-Noguchi mediums or into shake agar tubes.

Method of Shake Culture.—Another method for the isolation of single colonies is by shake culture prepared in the usual manner. The

Fig. 1.—Brush, consisting of from fifteen to twenty strands of aluminum wire, from 12 to 15 cm. in length. The brass clip (*b*) near the neck (*a*) keeps the teeth of the brush separated.

method has obvious disadvantages. The application of heat over the surface and the undue manipulation of the agar in separating it from the test tube cause it to become fragmented and turbid, which make the outlining of the colonies difficult. Another factor is the question of economy, for the test tubes are necessarily broken in separating the agar.

A simpler method for shake culture that I devised overcomes these difficulties. A glass tube open at both ends, of somewhat smaller diameter than the test tube to be used, is made to fit it not too snugly (fig. 3). The test tubes so prepared are sterilized by dry heat and filled with sterile melted agar in the ordinary manner. The agar of the inner tube is seeded at the proper temperature and then incubated. When ready for examination, the tip of a sterile forceps is inserted, and the inner tube is grasped, rotated a few times and removed. The test tube with the cylinder of agar is inverted over a sterile petri dish and is tapped so that the agar mold will fall out. Occasionally the inner tube will contain the agar mold when removed from the test tube. It can then

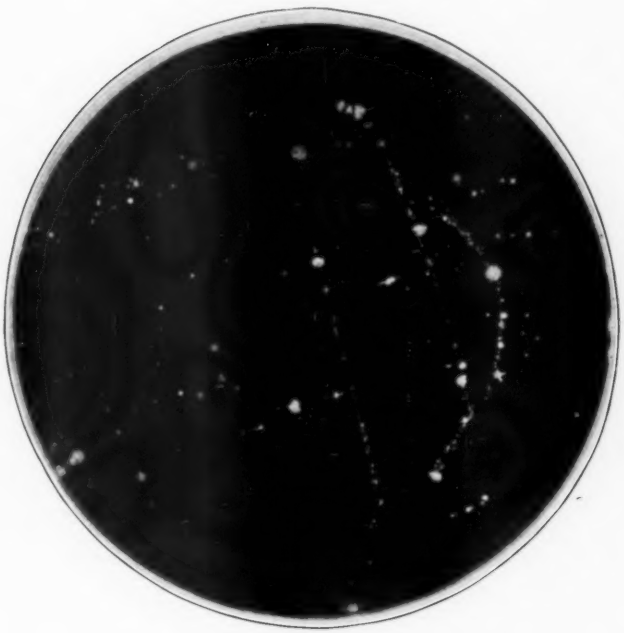

Fig. 2.—The mosaic appearance of the plate.

Fig. 3.—The simplified apparatus for shake culture devised by Cohen.

be put over a sterile petri dish, and with a sterile pipet the agar mold can be pushed out into the dish. The individual colonies are finally cut up and transferred to the proper mediums for further study.

The strictly anaerobic organisms failed to grow in solid mediums such as the shake agar tubes. The enriching of the mediums with ascitic fluid or the adding of a piece of sterile kidney tissue on the bottom of the agar tube involved too much manipulation, such as the pouring of mediums and, therefore, the absorption of oxygen. The addition of 0.2 per cent cysteine hydrochloride to the agar medium provided an anaerobic medium which was easy to prepare and which could be autoclaved. This procedure was suggested by the work of various authors. Quastel and Stephenson, employing casein digest broth, found that cysteine hydrochloride induced the growth of *Clostridium sporogenes* and *Cl. tetanomorphus* in an open tube. Valley [28] found that 0.2 cysteine agar was an excellent reducing agent in the medium and thus established favorable conditions for the development of anaerobic organisms.

Criteria for Calling an Organism Anaerobic.—In order to define criteria for aerobiosis, anaerobiosis and facultative anaerobiosis, in connection with the organisms likely to be found in abscess of the lung, the following studies were made:

A drop of twenty-four hour culture of an anaerobic streptococcus (streptococcus Schottmüller) in Smith-Noguchi medium was spread on blood plates, dextrose ascitic fluid agar and plain agar plates. Six plates were used in each case. Half of the plates were incubated anaerobically and half aerobically. The plates were examined in forty-eight hours.

A drop of twenty-four hour culture of an aerobic streptococcus was treated in an identical manner.

The strictly anaerobic organism grows on the surface of plates only under anaerobic conditions. The majority of aerobic organisms grow well on the surface of plates both under anaerobic and under aerobic conditions.

In tubes containing different amounts of broth, the distribution of oxygen in them will not be the same. The surface area of oxygen over the liquid will be smaller, the smaller the diameter of the tube, and the penetration or distribution of oxygen in the tube will be less, the higher the level of fluid. Gates and Olitsky [29] found that in a reducing medium such as dextrose broth a column length of from 8 to 16 cm. overlaid with paraffin oil favors the decolorization of methylene blue (methylthionine chloride, U. S. P.). They noted that a column of fluid 8, 10

28. Valley, G.: The Favorable Rôle of Cysteine in the Cultivation of Anaerobic Organisms, J. Bact. **17**:12, 1929.

29. Gates, F. L., and Olitsky, P. K.: Factors Influencing Anaerobiosis with Special Reference to the Use of Fresh Tissue, J. Exper. Med. **33**:51, 1921.

or 12 cm. long maintained at a constant temperature without agitation practically serves as a seal for the lower levels. Hence, anaerobic conditions can be found on the bottom of the tubes that are narrow enough and that contain sufficient amounts of fluid. Fluid mediums, therefore, are not sufficient criteria for determining whether an organism is anaerobic or aerobic.

It is safe to classify organisms that do not grow on plates aerobically, even under the most favorable circumstances of growth and of mediums, as strict anaerobes. Organisms that fail to grow aerobically on plates seeded with the pus, but which on further subculture grow aerobically, even in slight amount, may be called, for the sake of clearness, "doubtful" anaerobes.

BACTERIAL FLORA OF ABSCESS OF THE LUNG

From studies on the conditions of anaerobic growth, the following routine procedure was adopted as the one best suited to the isolation and study of the anaerobic and aerobic flora.

Procedure for the Cultivation of the Bacterial Flora of Abscess of the Lung.—Pus was obtained at operation in cases of abscess of the lung. The diagnosis of suppuration of the lung was verified by roentgen examination, when feasible by bronchoscopy and later at operation.

Smears of the pus obtained at operation were made and stained by Gram's method in order to determine the type of bacteria. Before culturing, the specimen was examined macroscopically, and the color, odor and consistency were recorded. If the pus obtained was sufficient in amount, blood plates and tubes containing the Smith-Noguchi medium were inoculated and immediately covered with petrolatum seal and incubated at 37.5 C. If only a small amount of pus was obtained, tubes containing the Smith-Noguchi medium were inoculated and then incubated for twelve hours. At the end of this period, the contents of the Smith-Noguchi tubes were centrifugated, the supernatant fluid was discarded, and a blood plate was inoculated with a drop of sediment and spread over the plate with an inoculating brush. Two other blood plates were inoculated with the same brush. This procedure was repeated with another set of two plates. The first set of three plates was placed in a moist jar made anaerobic by the method that I described,[30] and then were incubated for from seven to fourteen days at 37.5 C. At the end of this time, the plates were removed from the anaerobic jar, the individual colonies were picked under the microscope, and fresh Smith-

30. Cohen, J.: A Simple Central Catalyzing Station to Produce Anaerobiosis, J. Lab. & Clin. Med. **15**:262, 1929.

Noguchi mediums [31] were seeded as well as in "shake" 1 per cent dextrose agar tubes containing 0.2 per cent cysteine hydrochloride. The colonies in "shake" dextrose cysteine hydrochloride agar were later cut up and seeded in fresh Smith-Noguchi mediums. When pure cultures of organisms were obtained in the fluid medium, fresh blood plates were inoculated and incubated anaerobically and aerobically. Their morphology on fluid and solid mediums, as well as their fermentation on sugars, was studied. The other set of two plates was incubated aerobically at 37.5 C., and these were examined after twenty-four and forty-eight hours.

Bacterial Flora; Streptococcus.—In all of the cases studied, *Streptococcus nonhaemolyticus* (Gamma-Brown) was found. This organism was a "doubtful" anaerobe. In one case a strictly anaerobic streptococcus was isolated which gave off a fetid odor with gas in fluid mediums containing dextrose. This organism corresponded in all its properties to *Micrococcus foetidus* (Veillon), which will be described. In all other cases a streptococcus that did not grow aerobically at first and that grew only after the second or third subculture on plates was isolated.

Cultural Characteristics of Streptococcus-Gamma Commonly Isolated from Cases of Suppuration of the Lung.—This organism proved to be the easiest of all the organisms encountered in this study to isolate and to maintain in culture. While the majority of the organisms isolated from abscesses of the lung often failed to grow in culture even in the richest anaerobic mediums, it was always possible to isolate the "doubtful" anaerobic streptococcus. Another interesting feature was the influence of aerobic and anaerobic conditions on its growth on the surface of plates.

EXPERIMENT 1.—Smith-Noguchi medium was inoculated with pus obtained at operation and incubated for twenty-four hours at 37 C. At the end of this period, a drop of culture was spread on four blood plates and on four ascitic fluid agar plates. Half of the plates were incubated anaerobically and half aerobically. The Smith-Noguchi culture was left in the incubator for two, four and seven days. At the end of two days, a drop of the same culture was poured on the same number of plates, and these plates were incubated anaerobically and aerobically. In four days, and again in seven days, the same process was repeated.

The "doubtful" anaerobic streptococcus grew on all anaerobic plates, irrespective of the age of the culture. Growth on aerobic plates was obtained only with the two days old cultures.

EXPERIMENT 2.—The first subculture on anaerobic plates was again subcultured on plates and incubated under anaerobic and aerobic conditions; whenever there was growth on the plates incubated aerobically, the growth was again subcultured on plates and incubated under anaerobic and aerobic conditions.

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31. Repeated experiments have shown that when colonies of anaerobic organisms are seeded into large Smith-Noguchi tubes growth is less frequent than when the same colonies are seeded into tubes 10 by 1 cm. containing from 1 to 2 cm. of Smith-Noguchi medium.

There was growth on anaerobic plates whether the organism was subcultured from either anaerobic or aerobic plates. Growth aerobically on plates was obtained only when the organism was subcultured from an anaerobic plate and not from an aerobic one.

As is seen from experiments 1 and 2, an anaerobic environment is conducive to aerobic growth of certain "doubtful" anaerobic organisms and has a protective effect on them. Thus the organisms which were grown anaerobically grew both anaerobically and aerobically in subculture; but the organisms which had already grown aerobically and possibly were injured by exposure to the air grew anaerobically only in subculture. This phenomenon was not observed among all of the strains studied.

Growth: On plates the colonies are humid, round dewdrops which by transmitted light appear gray, glistening or opaque. They do not produce hemolysis on the blood plate. Good granular growth is obtained in both plain bouillon and 1 per cent dextrose broth. Organisms grow with a flocculent deposit on the bottom of the Smith-Noguchi tube, without the production of gas.

Fermentation of Sugars: As a rule, dextrose, saccharose and maltose were fermented. The remaining sugars, lactose, inulin and mannite, were fermented by some and not by others. Gelatin was not liquefied, and litmus milk was coagulated, with the production of acid in only four cases.

Agglutination: An attempt was made to find out whether these organisms belonged to a common serologic group. Streptococcus from one case (that of H. F.) was employed as an antigen to immunize rabbits, and immune serums were obtained. Rabbits were immunized the first two weeks by intravenous injections of increasing doses (from 1 to 12 cc.) of a saline emulsion of organisms killed at 60 C. for one hour, followed the third and fourth weeks by injections of increasing doses (from 1 to 12 cc.) of a saline emulsion of live organisms. The immune serums were tested against the strains of organisms isolated. While the homologous strain was agglutinated by its immune serum in the dilution of from 1 : 10 to 1 : 1,200 the various strains of streptococci isolated from abscess of the lung were not agglutinated by this serum.

From the foregoing data it is seen that the streptococci isolated did not give the same reactions to sugar, nor did they belong to the same serologic group.

Pathogenicity: Streptococci were not pathogenic to rabbits and guinea-pigs when from 1 to 2 cc. of a twenty-four hour culture in Smith-Noguchi medium was injected intravenously, and also locally, into the skin. When 0.5 cc. of this culture was injected intratracheally into

the bronchus of a dog by means of a bronchoscope,[32] a localized pneumonitis usually followed.

In view of the fact that a strictly anaerobic streptococcus had repeatedly been reported by various observers in abscess of the lung, the question arose as to whether the pus contained a mixture of a strict anaerobe and of a doubtful anaerobe, the latter overgrowing the strict anaerobe. The method of isolating a single bacterial cell with Chambers' apparatus was tried, in order to separate these two types of organisms. A few of the organisms were isolated by this method; they were grown and studied, but they finally grew aerobically.

An organism which on spread appeared to be *Streptococcus micros* was observed in some of the cases, but could not be identified culturally.

Diphtheroids.—Various types of gram-positive bacilli and coccobacilli were isolated which morphologically were pleomorphic and strongly suggestive of diphtheroids. A coccoid form appeared as a streptococcus, but gave off gas in fluid mediums containing dextrose; there was a small, stubby, bacillary form, and still another form was thick and somewhat curved, with rounded ends, about the size of the diphtheria bacillus. In their cultural characteristics these forms behaved like the "doubtful" anaerobic streptococcus, except that, unlike the streptococcus, they produced gas with an acrid odor in mediums containing dextrose (the odor could be easily differentiated from the one obtained in culture of *M. foetidus, Strep. putridus* and *Strep. anaerobius*). Not unlike the streptococcus, they varied in their reactions on sugars and coagulated milk and they did not liquefy gelatin.

In one case a small coccobacillus with pointed ends was isolated, which proved to be a strict anaerobe. On blood plate, it grew anaerobically as a small, opaque, granular colony with a raised center. After prolonged incubation in an anaerobic jar, the colony, on a blood plate, appeared as a homogeneous, round ball on top of a granular irregular surface. It was sharply outlined, moist and dome-shaped. In broth with a petrolatum seal, it grew half-way down the tube, with cloudiness of the mediums and a granular gray deposit on the bottom. In dextrose broth plus petrolatum seal, it grew, and there was a slight cloudiness of the mediums, with a granular gray deposit on the bottom and some production of gas. The greatest amount of gas was evolved in the Smith-Noguchi medium, with the evolution of a sharp acrid odor. Stab cultures in plain and dextrose agar remained sterile. The organism fermented dextrose, saccharose, lactose, maltose, inulin, mannite with acid and gas. It coagulated milk and did not liquefy gelatin.

32. Dr. Rudolph Kramer, of this hospital, performed the bronchoscopy on the dogs.

Micrococcus Foetidus (Veillon).—In one case a strictly anaerobic organism simulating *Micrococcus foetidus* was isolated. A description is given by Veillon. The following additional properties were observed. On blood plate, the colonies appeared round and dome-shaped, with a corrugated border. In fluid mediums, the organism occurred in pairs and in chains, giving off a characteristically fetid odor.

B. Ramosus.—This organism was isolated and described by Veillon and Zuber as a strict anaerobe. It is a small, slender bacillus with a cylindric and ovoid enlargement like the diphtheria bacillus. It has no spores; branching was noted by Veillon and Zuber. It stains feebly with Gram's stain. This organism coagulates milk and does not grow in gelatin. All cultures give off a peculiar fetid odor.

The following additional properties were found in connection with the organism. It retained the Gram stain. In culture, it was the size of a diphtheria bacillus; in pus, it appeared like needles of fir. On blood plates, it appeared as a small, round, opaque, yellowish-gray, raised, mucoid, glistening colony with regular edges. In bouillon plus petrolatum seal, growth appeared on the third or fourth day as a grayish granular deposit on the bottom with very slight general turbidity; there was no gas; the same character of growth was observed in dextrose broth. In the Smith-Noguchi medium, growth appeared as a flocculent deposit on the kidney tissue with a general turbidity plus a great deal of gas and a fetid odor (the odor is different from that given off by diphtheroids). After twenty-four hours, agar stab showed a flaky growth along the line of stab. After five days, dextrose agar stab showed a microscopic, pinpoint, translucent growth below the surface of the agar. On milk, gas was evolved, but the milk was not coagulated. Gelatin was not liquefied and showed a flocculent deposit about the kidney tissue. In ascitic fluid, sugar mediums, inulin, mannite and saccharose were fermented. In Hiss' serum water sugar mediums, saccharose and mannite also were fermented.

B. Melaninogenicum.—This organism is a strictly anaerobic, gram-negative bacillus; it was first described by Oliver and Wherry,[33] and later, more fully, by Burdon.[34] It was found to be a small, pleomorphic, slightly curved, thin, nonmotile, gram-negative, nonacid-fast rod with pointed ends. Large forms were also noted in pus and culture. It grew in symbiosis with the streptococcus, and it was difficult to isolate the bacillus in pure culture, but it grew well with the streptococcus. On blood plate it produced a black, extracellular pigment, melanin; the blood pigment disappeared from the plate and left the agar transparent.

33. Oliver, W. W., and Wherry, W. B.: Notes on Some Bacterial Parasites, J. Infect. Dis. **28**:341, 1921.

34. Burdon, K. L.: B. Melaninogenicum from Normal and Pathogenic Tissues, J. Infect. Dis. **42**:161, 1928.

The organism isolated in this laboratory was found to conform to this description and to possess the following additional properties: In pus, from lesions produced by injecting this organism intratracheally into the lungs of rabbits, the organism appeared in the shape of a coccobacillus. On blood plates, young colonies appeared with flat irregular borders and a raised center. Older colonies appeared as large, homogeneous, gelatinous, glistening mounds with irregular circinate borders; there was coffee-black amorphous material on top of the mound. The property to produce black pigment on a blood plate was lost in subculture whether from solid or from fluid mediums. Subcultures on a blood plate appeared as flat, round, regular, dry, darkly frosted, adhering, hemolytic colonies. The colonies appeared in from seven to fourteen days; rarely they appeared in two or three days. In fluid and also in solid mediums, the organism gave off a peculiar fetid odor. Gas was evolved in abundance in fluid mediums. It grew in symbiosis with the streptococcus gamma, a "doubtful" anaerobe, which in many instances failed to grow aerobically on plates, and therefore behaved like a strict anaerobe. In the Smith-Noguchi medium there was a slight general turbidity, with a greenish-black, flocculent deposit on the bottom and a great deal of gas and odor. No growth appeared in agar stab or in dextrose agar stab. A faint grayish deposit in the bottom of the tube appeared within from four to five days in plain and in dextrose broth when these were sealed with petrolatum. In gelatin, the growth appeared as a diffuse, blackish-gray deposit over the kidney tissue. Gelatin was not liquefied. In litmus milk the growth produced acid and gas. Milk was not coagulated. In ascitic fluid sugars there was no growth. In Hiss' serum water sugars there was slight growth. In dextrose, maltose and lactose the organism grew, with the production of acid. There was no growth in other sugars. The organism was fragile, and cultures became sterile after the fourth or fifth subculture. The addition of 1 cc. of 10 per cent gum arabic in 1 per cent dextrose broth revived the organism for further growth.

B. Furcosus.—This organism is a strictly anaerobic, small, gram-negative bacillus with rounded ends; it is slightly curved and has knob-like projections or piriform swellings at one end. It is somewhat thicker than *B. tuberculosis;* it is a nonspore bearer and is nonmotile. On the surface of agar, colonies appear like colonies of pneumococci.

The following additional properties were noted: In Smith-Noguchi medium there was a fine granular growth along the side of the tube, with the evolution of gas and a fetid odor. The production of gas was not lost in subculture. On the surface of the blood plate, it appeared as a round, dull, granular, moist colony, with a somewhat irregular, slightly raised dentate border. Younger colonies appeared like a small shirt button with a central depression. Older colonies had the appear-

ance of a stump of a tree with concentric circles. When grown in symbiosis with streptococcus, the colony had a varied granular deposit on its surface. Gas was not produced in broth or in dextrose broth. Gas was produced in dextrose, maltose, saccharose and mannite. It was not produced in lactose and inulin. Milk was not coagulated, and gelatin was not liquefied.

B. Thetoides.—A description of this organism is given by Besson.[35] It is a strictly anaerobic, gram-negative bacillus, with rounded or pointed ends; it is nonmotile and is a nonspore bearer. It appeared like a safety-pin, because of granules at either one or both ends, and of vacuolation in the middle of the cytoplasm. These granules were gram-negative. It was the size of the diphtheria bacillus, but was somewhat thicker. Occasionally larger forms were noted.

The following additional features were noted: In Smith-Noguchi medium the growth was characterized by a profuse cloudiness of the medium and a flocculent, stringy deposit on the bottom, with the evolution of gas and a fetid odor. Bouillon culture covered with petrolatum showed a granular deposit on the bottom. Dextrose, saccharose, maltose, lactose, mannite and inulin were fermented, with the evolution of gas. Litmus milk was coagulated and acidified. Gelatin was liquefied.

B. Fragilis.—This organism is a strictly anaerobic, tiny, gram-negative coccobacillus; it is nonmotile, is a nonspore bearer and is not acid-fast. On the surface of agar colonies were transparent, grayish-like colonies of pneumococci. The deep agar colonies were yellowish brown. The organism was very fragile.

The following additional properties were noted: On the blood plate, the colonies appeared as homogeneous, grayish, glistening mounds surrounded by a granular, tiny, scattering, needle-shaped border. By direct light, the colonies were hardly visible and were humid and transparent. In Smith-Noguchi medium, there was a generalized turbidity; the organism usually grew about from ½ to 1 inch (1.2 to 2.5 cm.) from the petrolatum seal, with a moderate amount of gas with a fetid odor. There was no precipitate over the kidney tissue. Gas was not produced in subculture. There was no growth in plain or in dextrose broth. The organism fermented maltose, dextrose, saccharose and lactose. Mannite and inulin were not fermented. Litmus milk was not acidified, and gelatin was not liquefied.

Staphylococcus Parvulus.—A full description of this organism is given by Veillon and Zuber, and quoted by Ford.[36]

35. Besson, A.: Practical Bacteriology, Microbiology and Serum Therapy, translated by H. J. Hutchens, New York, Longmans, Green & Company, 1913, p. 572.

36. Ford, W. W.: Text-Book of Bacteriology, Philadelphia, W. B. Saunders Company, 1927, p. 451.

The following additional features were noted: On the blood plate, the colonies appeared glistening, humid, dome-shaped and microscopic. In Smith-Noguchi medium, the organism grew as a slight gelatinous growth on the bottom of the tube under the kidney tissue, with no production of gas; the generalized turbidity was slight.

B. Fusiformis.—A full description of this organism is given by Ozaki, and quoted by Ford.[37]

The following additional features were noted: The organism is strictly anaerobic and gram-negative, with pointed ends and with fusiform bulging in the middle which holds two gram-positive bands. On blood plates, the colonies appeared as granular, round depressions (nucleus) in the middle of a pyramidal, irregular border. The growth was gray, mucoid, viscid and translucent and gave the appearance of piled up mucus. In Smith-Noguchi medium, the growth appeared as a greenish-black, gelatinous precipitate on the bottom of the tube over the kidney tissue, with a homogeneous slight cloudiness of the medium and the evolution of gas and a fetid odor. In subculture to the Smith-Noguchi medium, there was the same greenish-black precipitate, but the medium was clear. In plain broth with a petrolatum seal, there was a small granular deposit on the bottom of the tube with some gas and with slight cloudiness of the medium. The same type of growth was produced in dextrose broth. Acid and gas were produced in Hiss' sugars (dextrose, maltose, saccharose and mannite). Acid alone was produced in lactose and inulin. Gelatin was not liquefied. Gas and acid were produced in litmus milk.

Leptothrix.—A full description of the properties of this organism is given by Oliver and Wherry.[38]

The following additional features were noted: The organism is strictly anaerobic, gram-negative and threadlike, with gram-positive granules, appearing as streptococci. On the blood plate, the colonies were bizarre, with branching, a piled up center, irregular, finger-like projections and a corrugated border of the periphery (a Medusa-like colony). The growth appeared greenish by reflected light, and was mucoid gray by direct light. In Smith-Noguchi medium, there was generalized turbidity with the evolution of gas and a fetid odor. Hiss' sugars (dextrose, maltose, lactose, saccharose, mannite and inulin) were fermented, with the evolution of gas. Gelatin was not liquefied. Litmus milk was acidified and not coagulated.

Vibrio.—Anaerobic *Vibrios* were isolated by Muhlens, Veillon and Repaci from ulcerating lesions in tuberculosis of the lungs, by Soper

37. Ford (footnote 36, p. 288).

38. Oliver, W. W., and Wherry, W. B.: Leptothrix Innominata, J. Infect. Dis. **19**:299, 1916.

from pericardial effusion and by Tunnicliff from sputum in a case of acute bronchitis. A description of the properties of these organisms is given by the various authors.

The following properties were found to be possessed by the organism: It is a strictly anaerobic, gram-negative, curved, nonspore bearing organism; it appears singly or in bunches. On the blood plate, it appeared as a yellow, viscid, round, gelatinous mass. In Smith-Noguchi medium, it grew with diffuse cloudiness of the medium, with a gelatinous deposit on the bottom of the tube. There was a moderate amount of gas and some odor. Acid and gas were produced in lactose and saccha-

Type of Organisms Isolated in Sixteen Cases of Abscess of the Lung *

Name	Streptococcus Gamma	Diphtheroids	B. Melaninogenicum	B. Fusiformis	B. Ramosus	B. Fragilis	B. Furcosus	B. Thetoides	Str. Parvulus	Leptothrix	Vibrio	Other Anaerobes	Anaerobic Organisms
A. R.	+	+	+	+	..	..	..	..	..	..	..	Cl. cochlearum	.....
W.	+	+	+	..	..	+	..	..	..	+	..	.....	.....
C. G.	+	+	..	+	+	..	..	..	..	..	..	.....	.....
H. F.	+	+	+	..	+	..	..	..	..	..	..	.....	.....
D. R.	+	+	+	..	+	+	+	..	+	..	..	.....	B. friedländeri
N. D.	+	+	+	+	+	+	+	+	+	+	+	.....	.....
R.	+	+	+	..	..	..	..	..	..	..	..	.....	.....
F. L.	+	+	+	..	..	..	..	+	..	..	..	.....	.....
S. D.	+	+	+	..	+	..	..	..	..	..	..	.....	.....
S.	+	+	+	..	+	+	..	..	..	..	..	.....	.....
B. J.	+	+	+	..	..	..	..	..	..	..	..	.....	.....
E.	+	+	..	..	..	..	..	..	..	+	..	.....	Str. viridans
B. L.	+	+	+	+	..	..	..	..	+	+	..	.....	.....
R. M.	+	+	..	..	+	..	..	..	+	..	..	.....	.....
M. R.	+	+	+	+	+	..	+	..	..	..	..	.....	Str. viridans
K.	+	+	+	+	..	..	..	..	..	..	..	.....	.....

* The pus was obtained at operation.

rose. Acid was produced in maltose, mannite and dextrose. There was no growth in litmus milk and in gelatin.

Other Organisms.—Of the other anaerobic organisms isolated, *Clostridium cochlearum* was isolated in one case.

Of the aerobic organisms isolated, *B. friedländeri* was isolated in one case, and *Strep. viridans* in two.

SUMMARY AND CONCLUSIONS

As is seen from the accompanying table, in sixteen cases of abscess of the lung in which pus was obtained at operation, the "doubtful" anaerobic streptococcus and the diphtheroid were found in every case. *B. melaninogenicum* was found in fourteen cases, *B. fusiformis* in six, *B. ramosus* in eight, *B. fragilis* in five, *B. furcosus* in two, *B. thetoides* in three, *Staph. parvulus* in two, *Leptothrix* in three, *Vibrio* in one, *M.*

foetidus in one and *Cl. cochlearum* in one. Of the aerobic organisms, *B. friedländeri* was found in one case and *Strep. viridans* in two cases. It is seen, therefore, that the three organisms most commonly found in abscess of the lung were *Strep. gamma,* diphtheroid and *B. melaninogenicum.*

The flora is rich and varied and seems to occur in combinations of organisms. In the sixteen cases of abscess of the lung studied, in which pus was obtained at operation, streptococcus, diphtheroid and *B. melaninogenicum* were found in fourteen cases. In addition to the last three organisms, *B. fusiformis* was also found in five cases, making one combination; *B. ramosus* was found in another five cases, making another combination, and *B. fragilis* was found in still another five. Noteworthy, also, was the close symbiosis of the two organisms most commonly found in abscess of the lung, *Streptococcus gamma* and *B. melaninogenicum.* These facts raise the question whether this combination of organisms has a bearing on the etiology of abscess of the lung. This work will be the subject of another report.

THE INTRA-ABDOMINAL METHOD OF REMOVING INGUINAL AND FEMORAL HERNIA*

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Whatever else may be necessary as a part of the operative procedure for the cure of hernia, complete removal of the sac followed by high ligation or suture of the peritoneum is essential. All surgeons recognize this as the most important part of the procedure and many believe that in small-sized indirect hernias in children and young persons success is apt to follow regardless of the method employed for closing the canal. For hernias of large size, for direct hernia with imperfect development or absence of the conjoined tendon and for postoperative rupture, it is necessary to suture together certain fascial structures, such as the conjoined tendon and the shelf of Poupart's ligament. In many cases the use of fascial strips as recommended by Gallie is extremely important.

The numerous modifications of the original operations of Bassini and of Halsted have been directed largely, if not solely, to methods of closure of the canal and wound.

The old operative procedure consists of dissecting out the hernia from below, brushing off the anatomic coverings of the hernial sac, until it is clearly evident that the portion of the peritoneum above the neck of the sac is clearly exposed and ligated or sutured.

Surgeons of great skill are accomplishing this regularly in ordinary cases of hernia, and are succeeding in curing hernia in a high percentage of cases. Failures under the name of "recurrent hernia" in the hands of the best surgeons have amounted to no less than 5 per cent, and frequently after one or two years it will be found that in from 10 to 20 per cent of patients the result is a failure, i. e., a "recurrence."

Even in hernias of small size, when the dissection of the sac is performed from below through the inguinal canal, there is of necessity some injury to the cremaster muscle and fascia, and the line of cleavage between the peritoneal sac and the surrounding structures may not always be easily determined. In long-standing hernias of large size, the process of dissecting out the sac is tedious and may be difficult; the line of cleavage may be found only with the greatest difficulty, and all the time this is being done the inguinal canal is being greatly enlarged, surrounding structures traumatized, and important structures injured.

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* From the Department of Surgery, Medical College of Virginia.

In previous contributions I have described a method of approach for removing the sac of inguinal and femoral hernia from within the abdominal cavity. I am presenting now some improvements as gradually developed from experience in using the method in more than 1,700 cases.

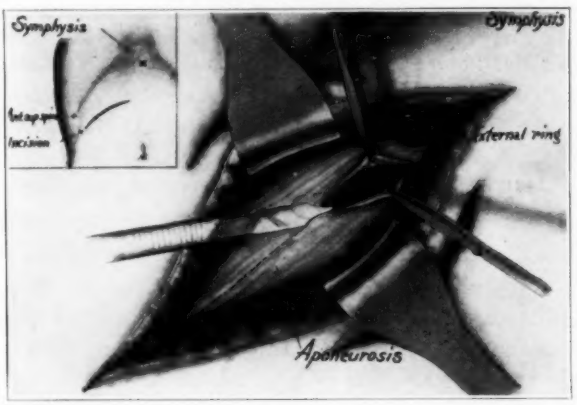

Fig. 1.—Operation for hernia, seen from the abdominal side. The incision is being made through the aponeurosis. The insert shows the skin incision.

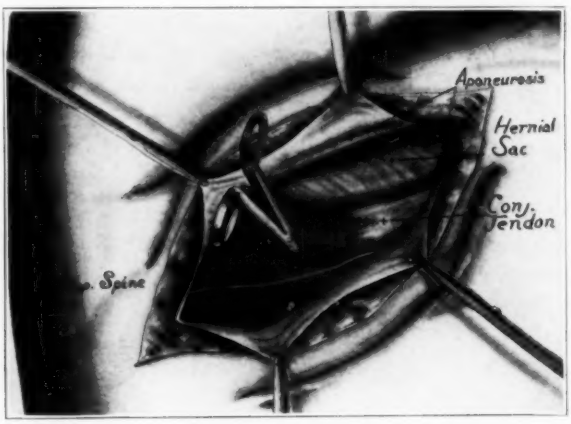

Fig. 2.—Operation for hernia, seen from the abdominal side. The fibers of the internal oblique are being separated well above the neck of the sac.

Many surgeons are recognizing the advantages of this method of approach in the treatment for hernia, and it is being employed with various modifications extensively. In observing other surgeons attempt the operation, I note that they either have failed to comprehend the

main points or have so modified the important technical parts of the procedure as to impair greatly the usefulness of the method.

For this reason, I have had a new series of illustrations made, which I hope may more accurately depict the operative procedure.

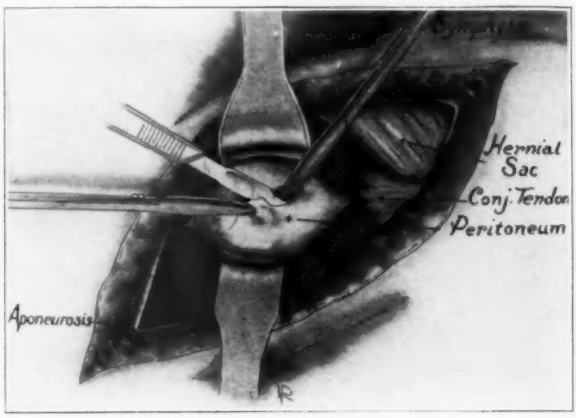

Fig. 3.—Operation for hernia, seen from the abdominal side. The peritoneum is being opened, about an inch above the neck of the sac.

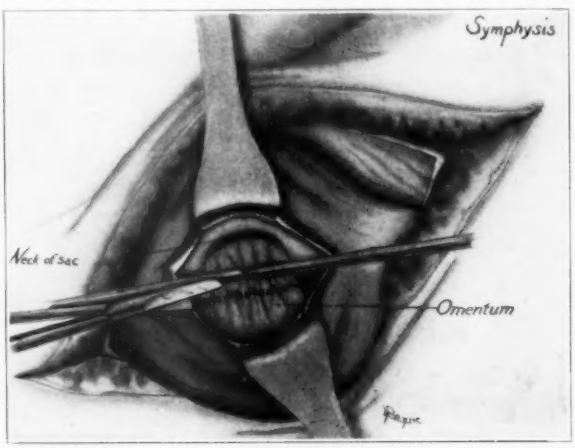

Fig. 4.—Operation for hernia, seen from the abdominal side. The omentum incarcerated in the hernial sac is ligated and cut, leaving the incarcerated portion in the sac.

The usual hernia incision is made, perhaps slightly higher than usual, the aponeurosis of the external oblique is exposed and divided as in the ordinary operation. The muscle fibers of the internal oblique

and the transversalis are separated, and the peritoneum is opened just as if an appendectomy were going to be performed.

From the peritoneal side it is easy to recognize and distinguish between hernia into the inguinal and femoral canals, direct and indirect

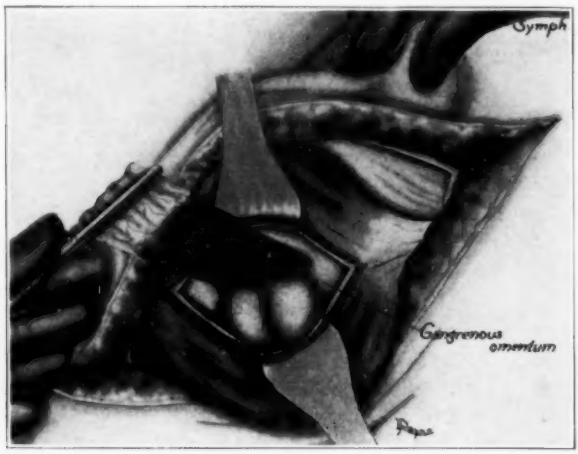

Fig. 5.—Operation for hernia, seen from the abdominal side. Gangrenous omentum is being pulled from above out of the hernial sac.

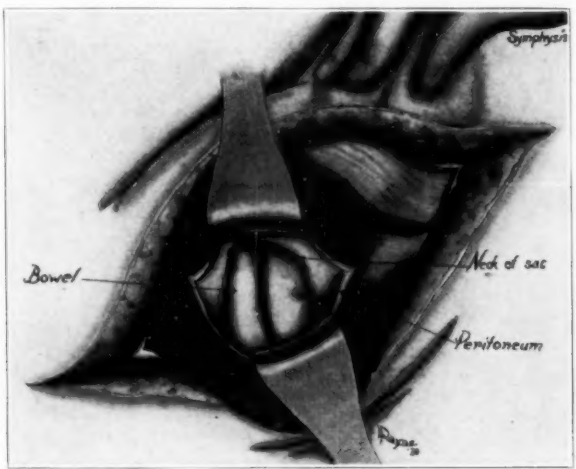

Fig. 6.—Operation for hernia, seen from the abdominal side. Two loops of bowel are incarcerated in the sac of the inguinal hernia.

inguinal hernia, unusual and anomalous types of hernia, the amount of redundant peritoneum and preperitoneal fat in and about the canal, the exact location of the bladder, vas deferens and important vessels, and whatever complications may exist.

In cases of strangulated or incarcerated hernia and of hernia with an anomalous type of sac, it needs little discussion to see the advantages of an approach from above. Incarcerated and adherent structures are safely separated from the hernial sac; restoration of circulation in the bowel

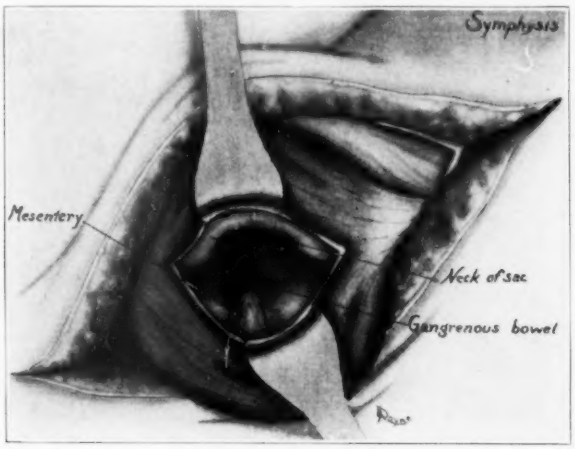

Fig. 7.—Operation for hernia, seen from the abdominal side. Strangulated bowel is returned out of the sac into the peritoneal cavity to be observed for restoration of normal color.

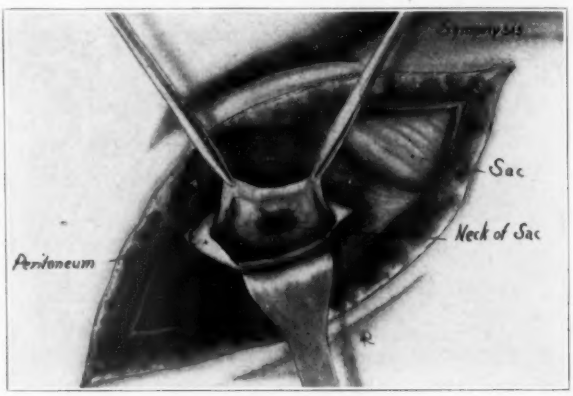

Fig. 8.—Operation for hernia, seen from the abdominal side. The peritoneal cavity is open and the neck of the hernia and surrounding peritoneum are seen from within the abdominal cavity.

occurs more promptly with the bowel free in the peritoneal cavity and the vessels free from traction; ligation and removal of omentum and resection of gangrenous bowel are more safely done under good

exposure; and coincident pathologic changes in the region of the hernial orifice may be recognized and dealt with if desired.

Dissection of the sac is greatly facilitated by enucleation from above, beginning in the natural line of cleavage between the peritoneum and its

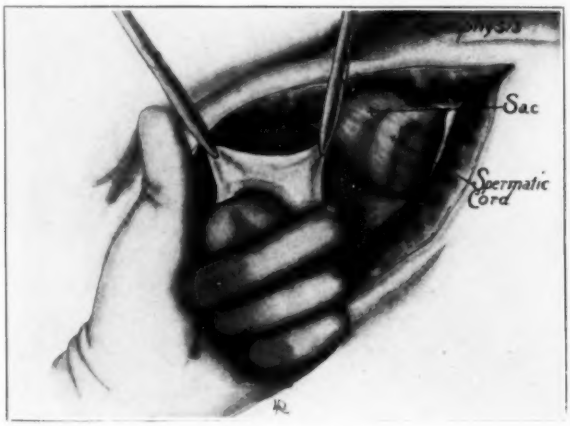

Fig. 9.—Operation for hernia, seen from the abdominal side. The finger is inserted into the hernia through its neck from the abdominal side.

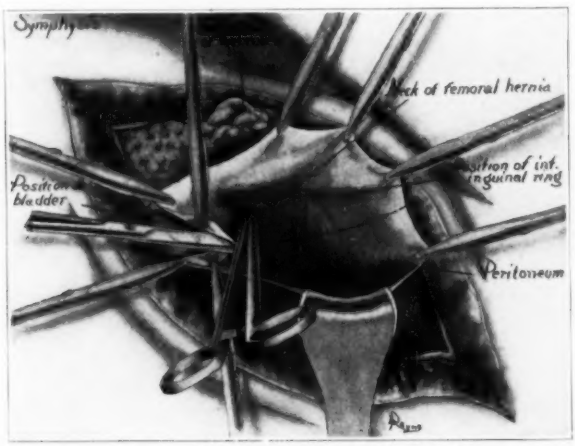

Fig. 10.—Operation for hernia, showing a femoral hernia from the abdominal side. The redundant peritoneum is being incised preliminary to removal of this and the sac of the hernia from within the abdominal cavity in exactly the same way as if it were an inguinal hernia.

nonadherent coverings above the neck. The line of cleavage is easily found; enucleation downward in the natural direction beneath the fascia is done with little trauma to the cremaster, internal oblique and other

muscles of the region. The bladder and structures of the cord, continuously in view, are gently brushed away and preserved from injury as enucleation proceeds. After removal of the sac, suture of the peritoneum is made at a point as high as desirable, sometimes 2 or 3 inches

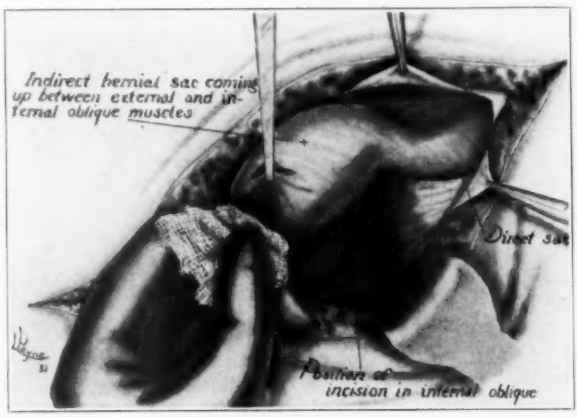
Indirect hernial sac coming up between external and internal oblique muscles
Direct sac
Position of incision in internal oblique

Fig. 11.—An interparietal (interstitial) hernia with a double "pantaloon" type of sac. The direct sac is in the inguinal canal; the indirect sac is between the aponeurosis and the internal oblique muscle. The aponeurosis has been split; both sacs are shown, the dotted line indicating the position of the muscle-splitting incision in the internal oblique.

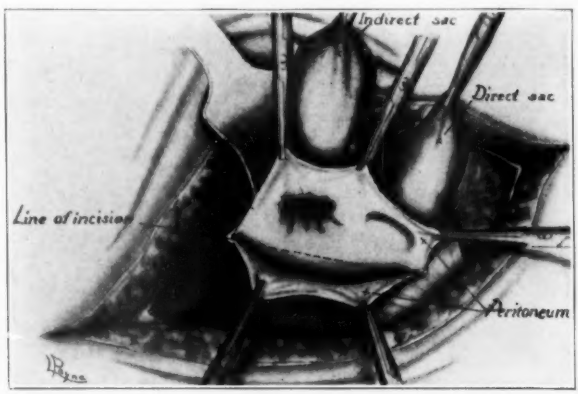

Fig. 12.—The peritoneal cavity is open, showing the openings of both sacs, and the sacs lifted up on forceps.

(5 or 7.6 cm.) above the original location of the neck of the hernia, and if one chooses, by catching the transversalis fascia the peritoneal suture is fixed to a higher position.

Whatever plastic procedure may be the preference of the individual surgeon, or may be the most suitable for the individual case, may be

employed in closing the canal and wound, and one is certain at the conclusion of the operation that the hernial sac is completely removed; and unless serious infection of the wound occurs postoperative rupture will not follow.

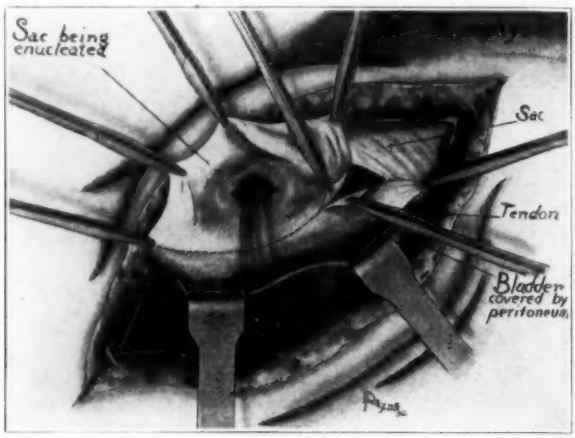

Fig. 13.—Operation for hernia, seen from the abdominal side. Redundant peritoneum for about an inch around the neck of the hernia is being dissected preliminary to enucleation of the sac. This shows the bladder, vas deferens and spermatic vessels safe from injury.

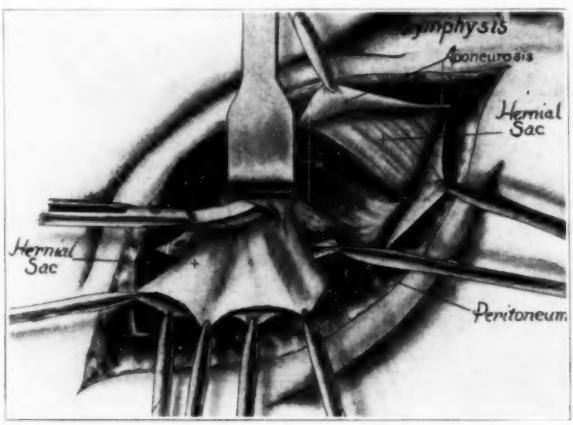

Fig. 14.—Operation for hernia, seen from the abdominal side. The lower edge of the peritoneum, being pulled upward, is easily enucleated after the insertion of blunt scissors into the space between the peritoneum and the overlying fascia.

At this point I would caution against the employment of certain modifications which I have seen other surgeons use. Instead of making the small muscle split incision for exposure of the peritoneum an inch

above the hernial orifice, one might be tempted to hook his finger or a retractor under the arching fibers of the internal oblique, and forcefully pull the muscles up to the point at which it is desired to open the peri-

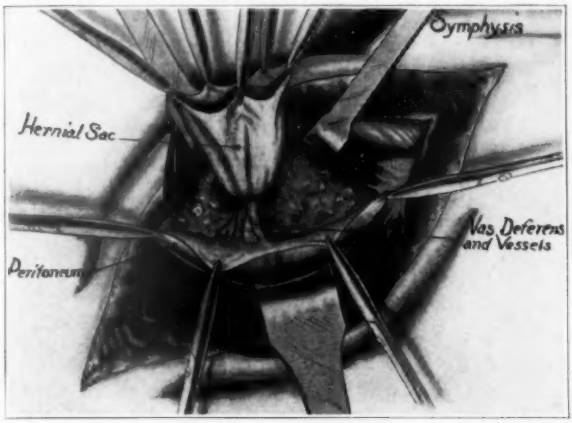

Fig. 15.—Operation for hernia, seen from the abdominal side. The sac, being pulled upward out of the inguinal canal, is easily separated from the vessels and vas deferens, beginning from the abdominal side.

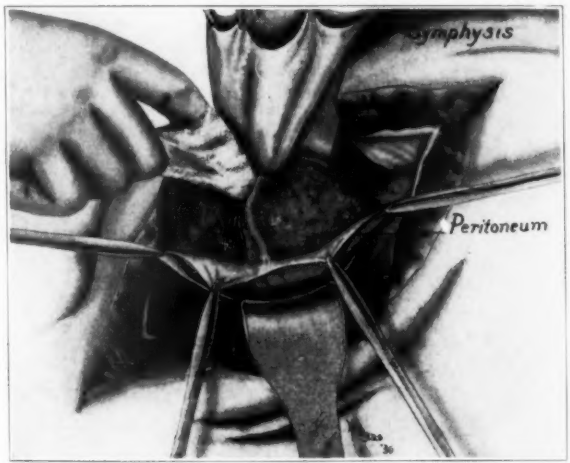

Fig. 16.—Operation for hernia, seen from the abdominal side. Aided by the gauze-covered finger, enucleation of the sac is almost completed and the vas and vessel are gently brushed away from the sac.

toneum, thus greatly overstretching the inguinal canal and seriously injuring the muscles of this region.

Others have been content, after making the muscle split incision and opening the peritoneal cavity, to suture the upper edge of the peritoneal

incision to the peritoneum behind the hernial orifice, without making any attempt to remove the sac. One might be tempted to do this in small children in whom hernia often is cured spontaneously, and in certain cases in which the patient is desperately sick with strangulated hernia.

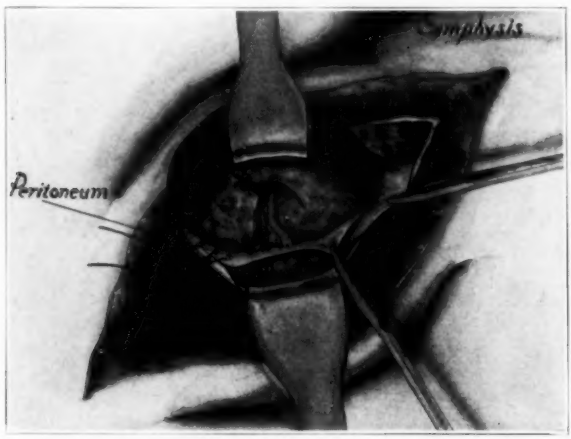

Fig. 17.—Operation for hernia, seen from the abdominal side. The sac has been completely removed from above downward, through an easy line of cleavage, leaving the fascia, vessels, vas and fat in situ uninjured. The cut edges of the peritoneum are being sutured.

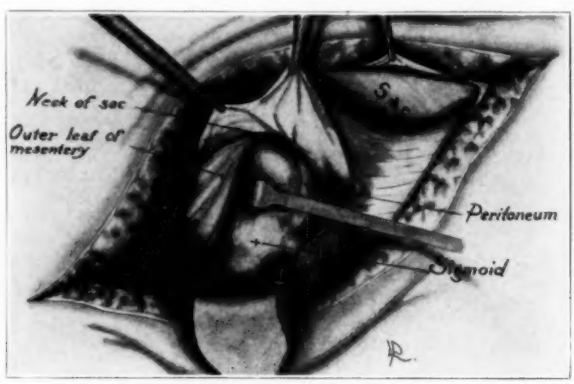

Fig. 18.—Sliding hernia of the sigmoid seen from within the abdominal cavity. Note that the bowel passes into the inguinal canal behind the sac, the neck of which is shown as a slitlike opening because it is lifted up by the sigmoid.

But no one should be deceived into believing that he has actually cured a hernia until the sac has been at least permanently separated from the peritoneal cavity by complete division at the highest portion of the neck, followed by ligation or suture of the peritoneum.

It is not my intention in this contribution to discuss the old question of "recurrences." It is better to discard the word "recurrence" and substitute for it "failure." Failures are of two types: (1) separation of the edges of the original incision at the point of ligation of the sac

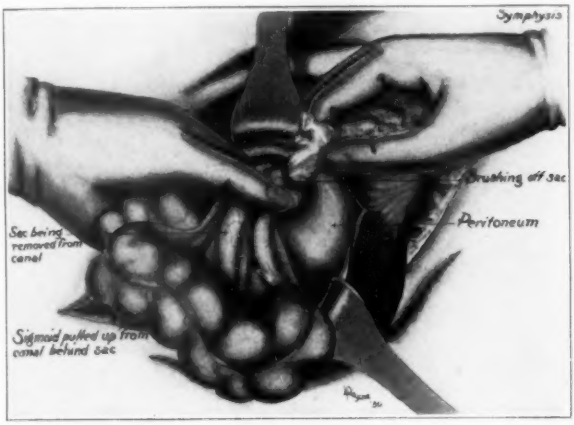

Fig. 19.—Operation for hernia, seen from the abdominal side. This shows a sliding hernia of the sigmoid after the sigmoid has been pulled out of the inguinal canal through an incision into the peritoneal cavity after splitting the muscles of the internal ring. The sigmoid has already been pulled out of the canal, and the sac is now being pulled out.

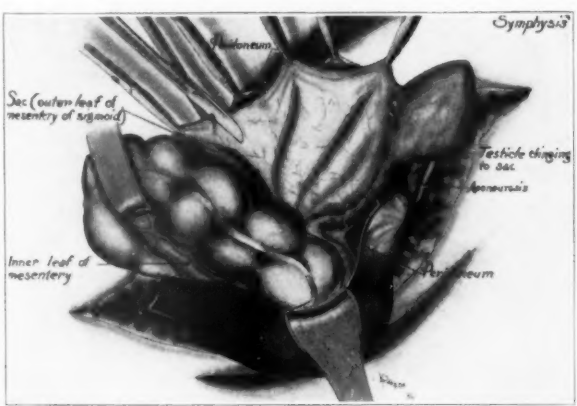

Fig. 20.—The sac of the sliding hernia, together with the outer leaf of the mesentery of the sigmoid is about to be removed by scissors dissection.

(rupture); (2) the overlooking, at the primary operation, of part of the original hernia proximal to the point of original ligation of the sac or the presence of another leg of the pantaloon type of hernia—usually the direct variety. Such sacs or proximal portions of the original sac

of course are not likely to be overlooked when careful surgeons are operating on hernias according to the method described here.

No statistical study of "recurrent hernia" can be made to tell the whole truth, and statistics can be made to conceal anything, even the

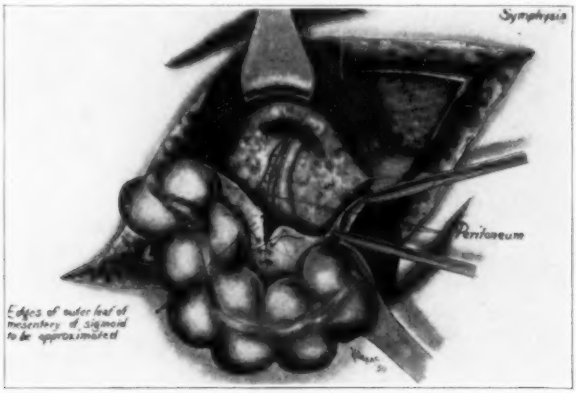

Fig. 21.—Operation for hernia, seen from the abdominal side. The sac of the sliding hernia, together with the outer leaf of the mesentery of the sigmoid has been removed, and the edges of the mesentery are being sutured together until the proper level is reached preliminary to closing the peritoneal cavity. The inguinal canal transmitting the vas and vessels is seen.

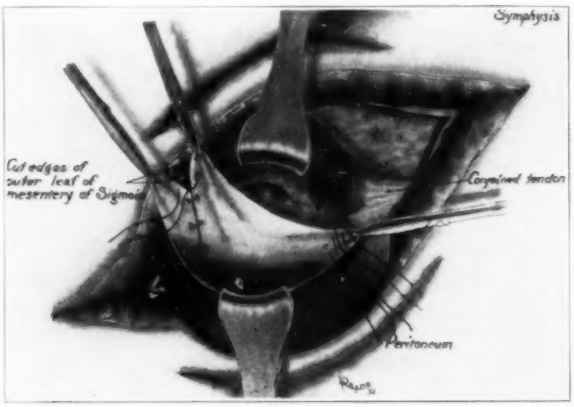

Fig. 22.—Operation for hernia, seen from the abdominal side. The outer leaf of the mesentery is completely sutured, and the two edges of the original incision into the peritoneal cavity are now being closed.

truth. The value of any method of operating for any disease cannot be determined with accuracy from statistics alone. If the procedure is based on sound principles, successes and failures are representative rather of the surgeon than of the method. Skilful surgeons often have

success with poor methods; amateurs and careless operators have a large number of failures by all methods.

For many years I have made painstaking efforts to examine the patients from time to time, to determine the number of failures. A large

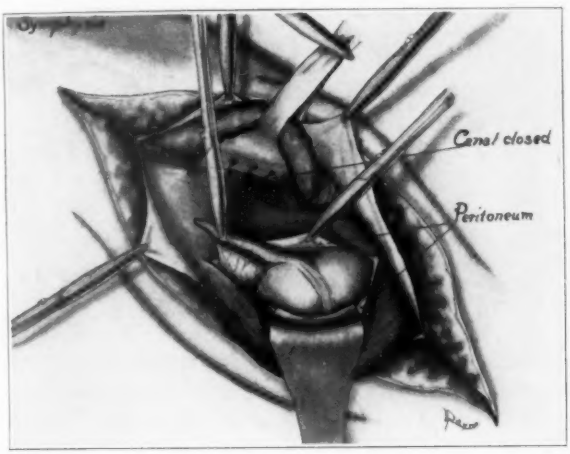

Fig. 23.—Operation for hernia, seen from the abdominal side. After the removal of the sac and closure of the canal, the appendix is delivered and about to be removed.

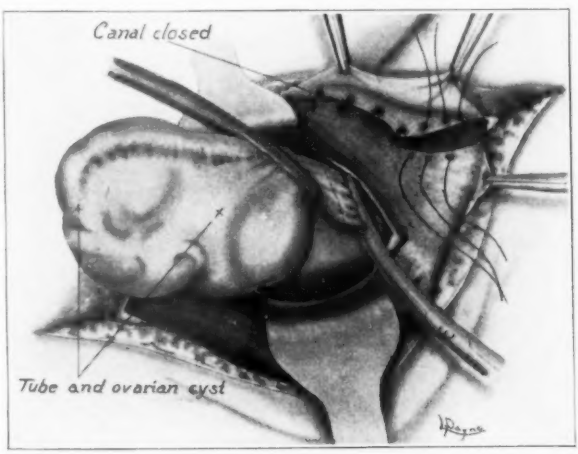

Fig. 24.—After removal of a hernia in a woman, the tubo-ovarian cyst is delivered into the wound, clamped and about to be removed.

percentage of patients were seen and examined at their homes by their doctors and by myself. In this way I have studied hundreds of patients after operation, and I have been able to find so few failures that I would not attempt to determine the percentage lest I myself be misled into a

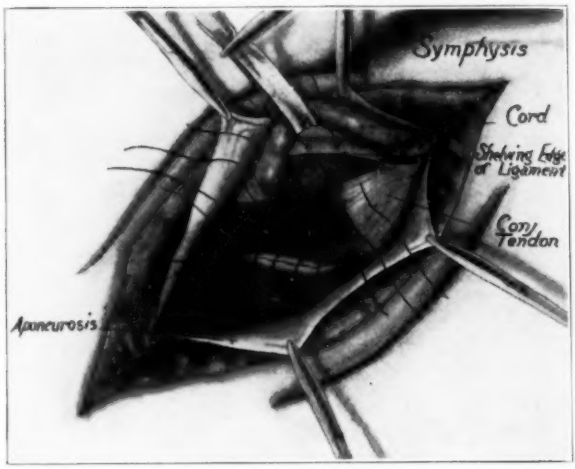

Fig. 25.—Operation for hernia, seen from the abdominal side. The incision in the peritoneum has been closed, the separated muscle fibers are being sutured together and the inguinal canal is being closed by sewing the conjoined tendon and arching fibers of the internal oblique muscle to the shelving edge of Poupart's ligament under the cord.

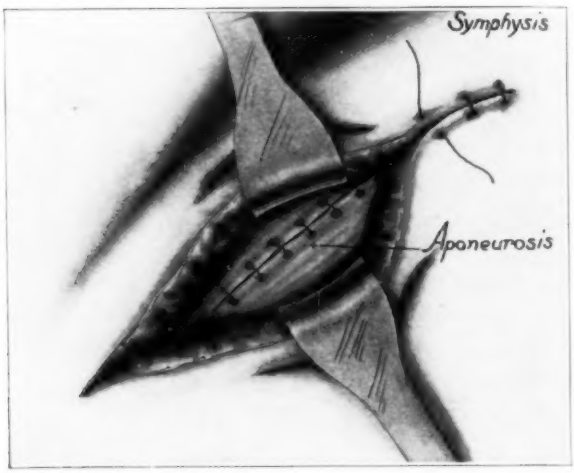

Fig. 26.—Operation for hernia, seen from the abdominal side. The aponeurosis is closed and the edges of the skin are being sutured.

false belief. Every one knows that grateful patients dislike very much to report failures. Ungrateful ones and those of hypercritical dispositions sometimes speak of unsuccessful results and present themselves with a bulge in some portion of the abdominal wall which on examination is found to be in no sense abnormal. I have been able to reexamine several hundreds of so-called difficult hernias of large size, and have seen a sufficient number of these put to the test of hard work, heavy lifting and other straining efforts, to lead me to the conclusion that this method of operating will permit the surgeon of average ability to be rewarded by a percentage of cures so much higher than that obtained by the better operative surgeons by the old method that the superiority of the abdominal approach admits of little debate.

The only failures that can occur in this method of operation would be those due to breaking of sutures, the result of postoperative coughing, or the opening of the wound with subsequent scar formation resulting from infection.

THE AERODYNAMICS OF BRONCHIAL OBSTRUCTION *

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It is well recognized that the intrapulmonary currents of air have an important bearing on bronchial obstruction. Obstruction from accumulation of secretions complicates bronchitis most frequently when the breathing is superficial. Both prevention and relief of obstruction may be promoted by the application of deep breathing exercises and of vigorous, well controlled coughing. Following the extensive investigations of Henderson and Haggard in the production of hyperpnea by the inhalation of carbon dioxide, the practice of administering this gas to patients after operation has become a routine measure in many surgical clinics. Nevertheless, the aerodynamics of bronchial obstruction is not understood in certain essential respects. It is not known, for instance, how deep breathing introduces air into a collapsed section of lung, the bronchi of which are filled with mucus; nor, under the same conditions, how cough evacuates the mucus. Conversely, the cause is not clear for the failure of deep breathing and coughing to obtain the results in many cases. Archibald [1] pointed out that inconstant and diverse effects of cough may be visualized plainly in man and in dogs during fluoroscopic examination of the bronchial tree with the use of radio-opaque oils. A column of such oil in a bronchus is usually thrown by a cough to the trachea, but at times the oil is thrown to the alveoli, or it is not displaced appreciably in either direction. The force of the impulse received by the oil is evidently governed by the vigor of the cough, but the direction of the impulse is not so determined. It is not known what determines the direction.

Another obscure subject in bronchial aerodynamics is that which relates to valvular action of masses obstructing the bronchi in the production of pulmonary atelectasis. Numerous cases are known [2] in which

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* From the Department of Surgery, Yale University School of Medicine.

1. Archibald, E., and Brown, A.: Am. Rev. Tuberc. **16**:111, 1927.

2. Bergamini, H., and Shepard, L.: Ann. Surg. **86**:35, 1927. Lilienthal, H., quoted by Jackson, C.: Mechanism of Physical Signs in Neoplastic and Other Diseases, J. A. M. A. **95**:639 (Aug. 30) 1930. Hegner, C.: Personal communication to the authors. Heuer, G.: Personal communication to one of the authors.

a part of the lung collapsed with a rapidity that would appear to rule out absorption as the mode of removal of the air; and to explain the circumstance it has been suggested [3] that the bronchus of the collapsed part was obstructed and the obstruction behaved as a valve permitting air to pass outward only. Each respiratory cycle then resulted in reducing by a fraction the volume of air in the lung distal to the obstruction, until atelectasis was complete. Most writers have discarded the theory,[4] but they offer no satisfactory reasons for doing so. Coryllos and Birnbaum [5] explained the rapid disappearance of air in these cases by their theories concerning absorption of alveolar gases. Of course, neither of these explanations accounts very well for the collapse in the instances in which careful search of the bronchial tree at autopsy failed to disclose the presence of secretions or other obstructing materials; but, in those in which obstruction was present, the simple mechanical theory of the valve cannot logically be discarded so summarily as it has been, especially since it is known to be a fact that bronchial obstructions have valvular actions at times. Jackson [6] has seen the phenomena bronchoscopically in patients on numerous occasions. The obstruction, whether it was a foreign body, a ball of inspissated secretion or a pedunculated intrabronchial neoplasm, was observed to move in rhythm with respiration in relation to the orifice of a bronchus or to an abnormal isthmus in the bronchial lumen, closing the passage during inspiration and opening it again during expiration. Van Allen and Adams [7] experimented with an artificial bronchial valve. A dog was anesthetized, and a cork perforated by a cannula was inserted into the right primary bronchus. A narrow rubber tube led from the cannula out of the trachea and extended to a glass of water in which its tip was submerged. After that, as long as the breathing was free and superficial, the water merely rose and fell a short distance in the tube with respiration and no air was lost from the tube; but when the outlet of the trachea was partly blocked during each expiration (in imitation of the action of the vocal cords during moaning, grunting and coughing) and the expirations became strained, the tube emitted a stream of bubbles at every breath and the obstructed part of the lung collapsed within a very few minutes. Van Allen and Adams preferred not to apply this to explain the collapse of the lung in clinical cases, thinking

3. Gairdner, W.: Month. J. M. Sc. **11**:122 and 230, 1850; **12**:440, 1851; **13**:2 and 238, 1851. Jackson C.: Mechanism of Physical Signs in Neoplastic and Other Diseases of the Lung, with Special Reference to Atelectasis and Emphysema, J. A. M. A. **95**:639 (Aug. 30) 1930.

4. Brunn, H., and Brill, S.: Ann. Surg. **92**:801, 1930.

5. Coryllos, P., and Birnbaum, G.: Obstructive Massive Atelectasis of the Lung, Arch. Surg. **16**:501 (Feb.) 1928.

6. Jackson (footnote 3, second reference).

7. Van Allen, C. M., and Adams, W.: Surg., Gynec. & Obst. **50**:385, 1930.

that the conditions of the experiment were different in one essential respect, at least, from those of clinical bronchial obstruction. In the former, the valve was directly faced on one side by the outer atmosphere, whereas, in the latter, the valve is faced on both sides by the bronchial atmosphere. They believed that an element of the same sort might be present in the bronchoscopic observations referred to, for there the bronchoscope led past the vocal cords and introduced the outer atmosphere directly and selectively to the outer face of the valve. Whether these differences were important in the matter of valvular action, and, if so, why they were, was not certainly known. An answer awaited a better understanding of bronchial aerodynamics.

During the course of some recent experimental work on problems pertaining to bronchial obstruction, a method was developed whereby the intrabronchial currents of air at the point of an obstruction could be observed directly and their forces measured. The method was an elaboration of that with a water valve, of Van Allen and Adams, but it obtained the essential physical circumstances of bronchial obstruction. Accordingly, the method was used in a series of experiments with the purpose of investigating systematically and defining the principles of the respiratory aerodynamics in bronchial obstruction. The varieties of bronchial obstruction that have been noted in man and the forms of respiration that accompany them were imitated in animals for the study. These experiments and their results form the subject of the present paper.

It will be necessary, first of all, to describe briefly a newly discovered function of the lungs, termed collateral respiration,[8] which enters very significantly into bronchial aerodynamics. This function depends on the fact that the lobular divisions of the bronchial tree of any one pulmonary lobe are interconnected abundantly at the periphery, rather than being independent as has been generally supposed. The interlobular septums of the lung are incomplete, and the alveoli at the planes of fusion of the lobules communicate with each other by minute passages (probably the alveolar pores of Kohn), and perhaps, too, by diffusion through the alveolar walls. The communication is brought spontaneously into operation when the bronchus supplying one lobule or group of lobules becomes obstructed, for then the obstructed part breathes by way of the collateral connections with the parts of the lobe remaining free. Thus, with inspiration, air that passes to the periphery of the free lobules enters collaterally into and inflates the obstructed lobules; and, with

8. Van Allen, C. M.; Lindskog, G. E., and Richter, H. G.: Yale J. Biol. & Med. **2**:297, 1930. Van Allen, C. M., and Lindskog, G. E.: Obstructive Pulmonary Atelectasis, Arch. Surg. **21**:1195 (Dec.) 1930; Collateral Respiration in the Lung, Surg., Gynec. & Obst. **53**:16, 1931. Van Allen, C. M.; Lindskog, G. E., and Richter, H. G.: J. Clin. Investigation **10**:559 (Aug.) 1931.

expiration, air to be discharged from the obstructed lobules escapes by the same path into the free lobules and passes out with the expired air of those parts. Respiration may continue in this manner and maintain the inflation of the obstructed lobules as long as obstruction lasts. Examples are known in man,[9] as well as in experimental animals,[10] in which large sections of lobes remained fully air-containing indefinitely after bronchial obstruction. Collateral respiration is interrupted whenever the patency of the alveoli and bronchioles at the planes of fusion of the obstructed and free parts of the lung is lost, as may occur from accumulation of inflammatory exudates and secretions or from insufficient respiratory expansion. There is no provision (in man and dog) for collateral respiration between the lobes of the lung. The interlobar fissures and septums are complete and prevent it. When the bronchus supplying one or more entire lobes is obstructed, the airways of those parts are necessarily isolated from the airways of the rest of the lung and from the outer atmosphere. Broadly speaking, collateral respiration serves the bronchial system in the same economic capacity as does collateral circulation the vascular system.

EXPERIMENTAL METHOD

The experiments were acute. For each one a dog was anesthetized and tracheotomized, and two long cannulas were introduced through the trachea into one bronchus. One cannula was entered a little farther than the other, and its tip was expanded in the bronchus to produce an air-tight fit, while the internal end of the other was laid quite freely in the lumen. The external ends were connected by interposing a valve between them. This produced an extension of the bronchial passage to the outside and back along a U-shaped course (fig. 1). The valve served to obstruct the air currents respired through the bronchial passage, and it was so constructed as to exhibit nicely to open view the behavior of the currents at the obstruction (valve to be described). Two manometers were attached to the passage, one distal to the valve and the other proximal to it. A third cannula was introduced through the wall of the chest into the pleural cavity at a point immediately over the obstructed lobe. It was attached to a third manometer.

The circumstances of the experiments were caused to vary in certain respects. On different occasions, two positions and three types of obstruction were formed and two types of breathing were induced. Thus, there was lobular obstruction (figs. 1 and 2 *A*, *B* and *C*), or that with the cannula fixed in the stem bronchus of the right lower lobe at a point just distal to the first branch; and lobar obstruction (fig. 1, *K*, and fig. 2, *D*, *E* and *F*), or that with the cannula fixed in the right primary bronchus at a point just proximal to the branches supplying the lower and accessory lobes. Also, there were total obstruction (fig. 2, *A* and *D*), or that with the cannular passage closed continuously on both sides of the valve; simple inspiratory obstruction (fig. 2, *B* and *E*), or that with the valve arranged

9. Van Allen, C. M., and Ch'in, K.: Work in progress.

10. Adams, W.: Proc. Soc. Exper. Biol. & Med. **27**:982, 1930. Brill, S., and Brown, A., quoted by Jackson (footnote 3, second reference). Van Allen, Lindskog and Richter (footnote 8, first reference).

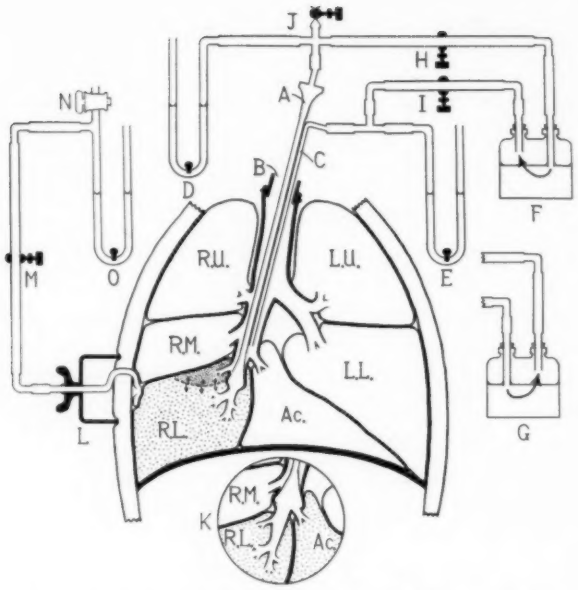

Fig. 1.—Diagram of a frontal section of a dog's chest walls and lung and of the apparatus arranged in place. *A* indicates the dilatable bronchial cannula, fixed in the stem bronchus of the right lower lobe (*R.L.*) at a point just distal to the first branch, as used to produce lobular obstruction; the arrows below, paths of collateral respiration between the obstructed part (lightly dotted) and the free part (heavily dotted) of the lobe; *K*, insert showing point of fixation of the dilatable cannula in the right primary bronchus just proximal to the bronchi of the right lower (*R.L.*) and accessory (*Ac.*) lobes, as used to produce lobar obstruction; *B*, tracheotomy opening; *C*, nondilatable cannula, terminating freely in the right primary bronchus; *D* and *E*, manometers connected to the cannulas; *F*, water valve connecting the cannulas, as used for simple inspiratory obstruction; *G*, insert showing arrangement of water valve for simple expiratory obstruction; *H* and *I*, pinch-cocks to be closed for total obstruction; *J*, pinch-cock to be opened for relief of obstruction; *L*, pleural cannula; *M* and *N*, cocks; *O*, pleural manometer. In some experiments manometers, *D* and *E*, were replaced by tambours with writing arms and a kymograph.

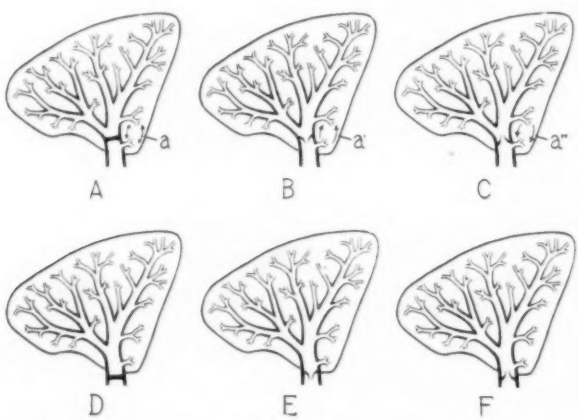

Fig. 2.—Diagrams of the bronchial tree of the dog's right lower pulmonary lobe, showing in principle the conditions of obstruction that were studied. *A*, *B* and *C* indicate lobular obstruction; *a*, *a'* and *a''*, paths and directions of collateral respiration; *D*, *E* and *F*, lobar obstruction (the second lobe, which was included, is not shown); *A* and *D*, total obstruction; *B* and *E*, simple inspiratory obstruction; *C* and *F*, simple expiratory obstruction.

so as to close the passage only at inspiration, and simple expiratory obstruction (fig. 2, *C* and *F*), or that with the valve arranged so as to close the passage only at expiration. And, finally, free breathing, or that with the trachea kept open about the cannulas continuously for respiration of the nonobstructed parts of the lung, and coughing breathing, or that in which the effects of cough were imitated from time to time with certain manipulations at the tracheal outlet were induced (see under technic). These experimental variables were used in twelve different combinations, and each combination was investigated on from two to six occasions during the course of eleven experiments.[11]

Each experiment was divided into parts, the parts dealing with different combinations of the experimental variables. To start each part, the obstruction was relieved for a few minutes (fig. 1, pinch-cock *J* opened), the apparatus was adjusted to provide the desired circumstances, and then the obstruction was suddenly instituted (fig. 1, pinch-cock *J* closed) at the height of either inspiration or expiration. Observations were begun immediately thereafter. These included reading the three manometers,[12] both at inspiration and at expiration, and watching the behavior of the air at the valve. They were made simultaneously by several observers and were repeated as often and as long as necessary to demonstrate the changes that occurred. One experiment differed from the rest, in that the dog was dead and respiratory excursions of the walls of the chest were made artificially.

The results of the experiments are presented in the form of outlines and charts. Duplicate data are omitted as far as possible, but reference is made only to those features of the reactions that were repeatedly seen in the same forms and were believed to be quite characteristic. The varieties of reaction that occurred in the different combinations of experimental variables are illustrated.

APPARATUS

Dilatable Bronchial Cannula (fig. 3).—The mechanism of this instrument has been explained elsewhere.[13] The cannula was 40 cm. in length and 0.25 cm. in internal diameter. The end for introduction could be dilated forcefully in situ in the bronchus by revolving a screw at the other end, and it then presented a narrow ring of metal and rubber to the inner surface of the bronchus for attachment. Dilatation could be extended sufficiently to stretch tightly a dog's bronchus of any size. The attachment was secure against accidental dislodgment, and it was selective and thoroughly air-tight.

Nondilatable Bronchial Cannula (fig. 1, *C*).—This instrument was a simple straight metal tube, of the same internal diameter as the dilatable cannula and a little shorter.

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11. These were the last of a series of thirty-two experiments. The earlier ones were occupied in developing the various aspects of the problem and in standardizing the technic. The data obtained from the earlier experiments helped greatly to confirm the conclusions that have been reached, but they will not be referred to directly in this paper because of the lack of uniformity in experimental method that existed.

12. The manometers were read directly. It was necessary to obtain absolute pressures, and the use of floats and writing arms for automatic recording was undesirable because of the inaccuracy produced by friction.

13. Van Allen, C. M.: Yale J. Biol. & Med. **2**:297, 1930.

Pleural Cannula[14] (fig. 1, *L*).—This cannula consisted of a metal tube bent approximately to the shape of a question mark, together with a metal housing and a winged nut. The hooked portion of the cannula, which was meant to lie in the wall of the chest and pleural cavity, had a closed rounded end and a fenestrum on the concave aspect near the end. The fenestrum was for communication with the pleural cavity. The straight portion carried the connection with the manometer, also the housing and nut. The latter served to hold the cannula in place on the chest. A pinch-cock was situated between the cannula and manometer, to be closed during introduction of the cannula (forcing of the hooked portion bluntly through the soft tissues of the wall of the chest) and during adjustment of the manometer to atmospheric pressure. The arrangements thus permitted an entirely "closed" operation of the instrument.

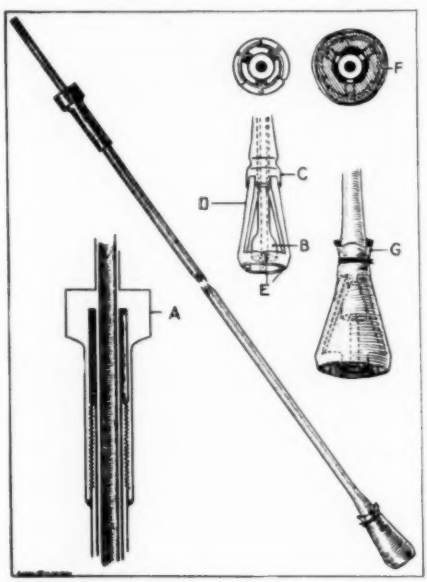

Fig. 3.—Plan of the dilatable bronchial cannula. In the center is shown a cannula ready for use; above, detail of the dilatable end, when dilated and when collapsed. *B, C, D* and *E* indicate parts of the dilating mechanism; *F* and *G*, rubber cap. Below is shown the detail of the reverse end. *A* indicates a screw for producing dilatation.

Valve (fig. 1, *F* and *G*).—This was a glass, double-necked bottle partly filled with water, which was fitted with two corks each pierced by a glass tube. One tube terminated above the water and the other extended from 1 to 2 mm. under it. The tubes carried the connections with the bronchial cannulas. Thus, the arrangement was such as to allow air to flow through the bottle from one cannula to the other only in the direction from the submerged tube to the elevated one, and to betray delicately by changes in the level of the water in the submerged tube the movements of air in either direction.

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14. Adapted from a cannula used in the laboratory of Dr. I. S. Ravdin.

Manometers.—These instruments differed from the common U-shaped manometer in one important respect. At the bend of the U was a set-screw by which the lumen could be narrowed to any degree. This was used to dampen the after-swing of the column of fluid and to increase the accuracy of the readings at times when the rate of respiration was too rapid and the period of swing too short to allow the column to come to rest for reading without such dampening. Water was the medium, it being best adapted to register the small pressures encountered. Tambours were employed in place of manometers in a few experiments, in order to secure kymographic records. Particular care was taken to equalize the tension of the tambours and to make the tracings directly comparable.

SPECIAL TECHNIC

Preparation of the Dog.—A preliminary hypodermic injection of morphine, from 0.030 to 0.045 Gm., and atropine, from 0.002 to 0.004 Gm., was given. The dog was anesthetized with ether and fastened in the dorsal recumbent position. The trachea was exposed by midline incision, and it was completely severed from the larynx. The tracheal opening was fitted with a glass sleeve, tied in place, to hold it wide for instrumentation and to control oozing of blood. The anesthesia was then carried on by directing a stream of ether vapor and air at the tracheal outlet.

Management of Breathing.—Institution of free breathing required no additional adjustment, for there was ample space in the trachea beside the cannulas for passage of the air respired by the nonobstructed parts of the lung. The respirations were regulated and kept at moderate depth and steady rate, as nearly as possible, by adjusting the composition of the ether-air mixture. In preparation for experiments requiring the use of cough, the dog was given a smaller dose of morphine than otherwise and was kept under a very light anesthesia with ether. This caused deep and somewhat irregular respiration. When a cough was wanted, the breathing was watched carefully and at the height of an unusually full inspiration the outlet of the trachea was occluded completely with the finger, the occlusion was maintained during from one third to one half of expiration, and then the outlet was suddenly released. This maneuver produced momentary back pressure in the lower respiratory passages and explosive discharge of the imprisoned air. The dog usually reacted to the transient tracheal block with forceful expiratory effort, and, although the force of the act was less than that of the average natural cough, the essential effects of cough seemed to be represented. The act was always repeated several times to permit accurate observations of the effects.

Autopsy.—The apparatus was left in place at the termination of the experiment, the dog was killed by intravenous injection of ether, and autopsy was performed. The degree of inflation of the obstructed part of the lung was noted, and pathologic lesions were searched for. The position of the dilatable cannula was checked, and vigorous tests were made to determine the degree of air-tightness at the attachment.

RESULTS

FREE RESPIRATION

A. Obstruction: Lobar and Total (Fig. 2, *D*).—Begun at Height of Expiration (Observed Ten Minutes): Figure 4, *a*, shows that at first the distal pressure (intrabronchial pressure distal to obstruction; recorded by manometer, fig. 1, *D*) oscillated regularly with respiration from 0.4

to —2.8 cm. of water; the proximal pressure (intrabronchial pressure proximal to obstruction; recorded by manometer, fig. 1, *E*) oscillated similarly from 0.2 to —0.2 cm.; the intrapleural pressure oscillated similarly from —5.4 to —8.8 cm. There was no important change. The obstruction was released.

Observation Begun at Height of Inspiration (Observed Thirty-Seven Minutes): It is seen in figure 4, *b*, that at first the distal pressure oscillated from 1.6 to —2.4 cm. of water. It fell gradually to a zone from 0.4 to —4 cm. after twenty minutes, and then it changed no more. The other pressures were essentially the same as in part *a*.

B. Obstruction: Lobar and Simple Inspiratory (Fig. 2, *E*).—Begun at Height of Expiration (Observed Twenty-Six Minutes): In figure 5

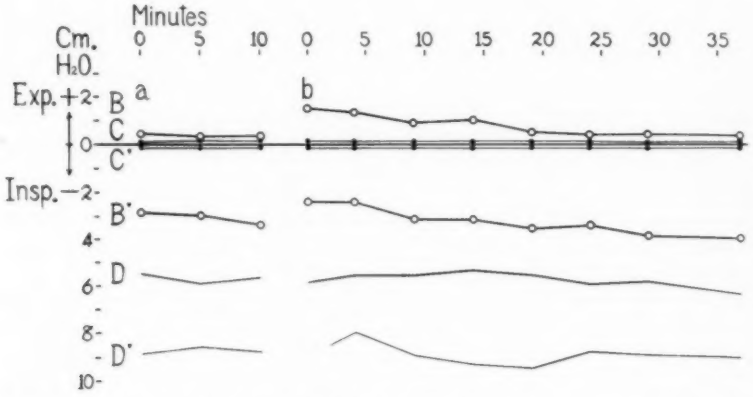

Fig. 4.—Total, lobar obstruction (see plan, fig. 2, *D*). *0 cm. H_2O* indicates the level of atmospheric pressure; *B* and *B'*, curves representing the expiratory and inspiratory limits, respectively, of the range of oscillation of the intrabronchial pressure distal to the obstruction; *C* and *C'*, the same type of curves for the intrabronchial pressure proximal to the obstruction; *D* and *D'*, the same type of curves for the intrapleural pressure; *a*, period with obstruction and observations begun at the height of an expiration (no tidal air in the obstructed part of the lung); *b*, period with obstruction and observations begun at the height of an inspiration (tidal air included in the part).

it is seen that at first the distal pressure oscillated from 1.8 to —5.6 cm. of water; the proximal pressure, from 0.2 to —0.2 cm.; the intrapleural pressure, from —4.6 to —11 cm. With the first expiration, air bubbled heavily at the valve (leaving the lung); with the second, slightly less bubbling occurred; with the third, still less; with the fourth, one bubble passed; then no more passed, and the water in the submerged tube merely rose and fell a few centimeters with respiration. During the first four breaths, the level of the distal pressure at expiration fell rapidly to

0.3 cm. of water, and then it remained at that level. Other pressures showed no important changes throughout.

C. Obstruction: Lobar and Simple Expiratory (Fig. 2, *F*).—Begun at Height of Expiration (Observed Sixty Minutes): Figure 6 shows that at first the distal pressure oscillated from 0.4 to —6.6 cm. of water; the proximal pressure, from 0.2 to —0.2 cm., and the intrapleural pressure, from —4.3 to —11 cm. With every inspiration for twelve minutes air bubbled heavily at the valve (entering the lung), and the distal pressure rose steadily to a zone from 5.6 to —2.6 cm. of water. Bubbling was then slightly less for twenty minutes, and the distal pressure rose more gradually to a zone from 6 to —1.2 cm. After that, bubbling was still less and occurred only at every third or fourth inspiration. There was

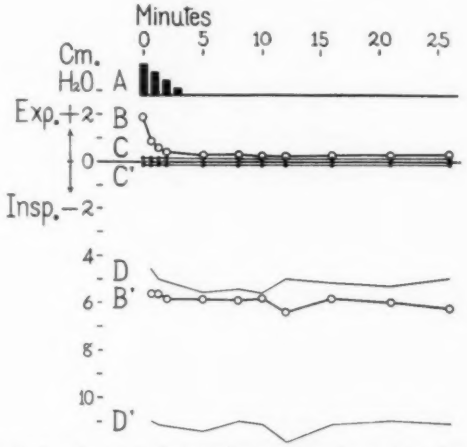

Fig. 5.—Simple inspiratory, lobar obstruction (see plan, fig. 2, *E*). *A* indicates columns representing relatively the amounts of air expelled through the valve at each expiration. Obstruction and observations were begun at the height of an inspiration (tidal air in the obstructed part). The designations are otherwise the same as in figure 4.

no further important change in pressure. The other pressures showed no important changes throughout. The dog was killed. The distal pressure rose immediately to 9.2 cm. of water; the intrapleural pressure to 2.6 cm. Autopsy showed that the obstructed lobes were markedly emphysematous and that the mediastinum was displaced distinctly to the left.

D. Obstruction: Lobular and Total (Fig. 2, *A*).—Begun at Height of Expiration (Observed Ten Minutes): In figure 7, *a*, it is seen that at first the distal pressure oscillated from 1.6 to —1.6 cm. of water, and the proximal pressure, from 0.2 to —0.2 cm. There was no important change. The obstruction was released.

Obstruction Begun at Height of Inspiration (Observed Thirty-Five Minutes): Figure 7, *b*, shows that the pressures were practically the same as in part *a* and remained so throughout.

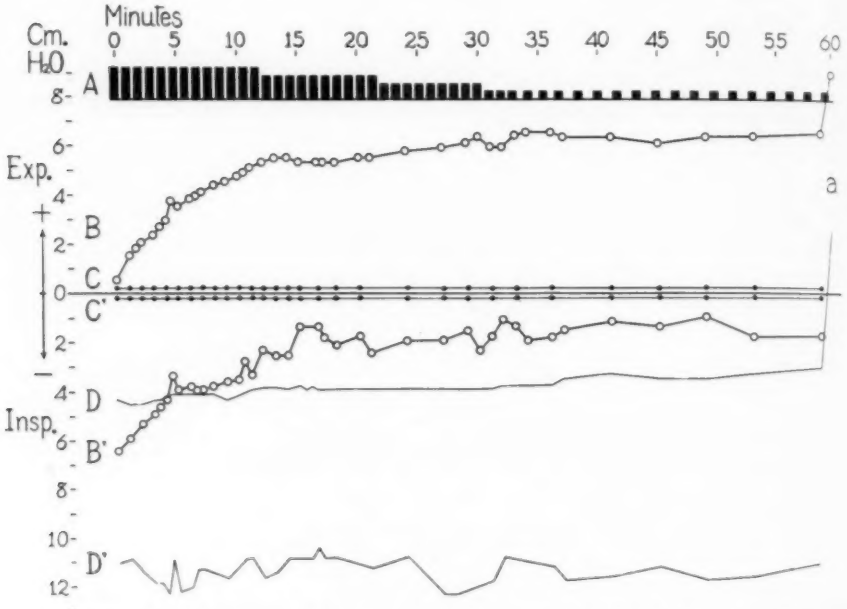

Fig. 6.—Simple expiratory, lobar obstruction (see plan, fig. 2, *F*). *A* indicates columns representing relatively the amounts of air received through the valve at each inspiration. Obstruction and observations were begun at the height of an expiration (no tidal air in the obstructed part). The designations are otherwise the same as in figure 4. The dog was killed at sixty minutes. The readings made immediately after death are indicated by *a*.

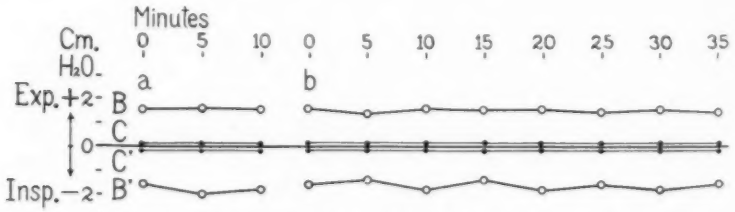

Fig. 7.—Total, lobular obstruction (see plan, fig. 2, *A*). The designations are the same as in figure 4, omitting intrapleural pressures.

E. Obstruction: Lobular and Simple Inspiratory (Fig. 2, *B*).—Begun at Height of Expiration (Observed Thirty-five Minutes): It is seen in figure 8 that at first the distal pressure oscillated from 1.2 to —5 cm. of water; the proximal pressure, from 0.3 to —0.3 cm. There was no important change. Air bubbled heavily at the valve (leaving

the lung) with each expiration throughout. The dog was killed. Autopsy showed that the obstructed part of the lobe was normally inflated.

F. Obstruction: Lobular and Simple Expiratory (Fig. 2, *C*).—Begun at Height of Expiration (Observed Thirty-Five Minutes): Figure 9 shows that at first the distal pressure oscillated from 3.2 to —2 cm. of water; the proximal pressure, from 0.2 to —0.2 cm. There was no important change. Air bubbled heavily at the valve (entering

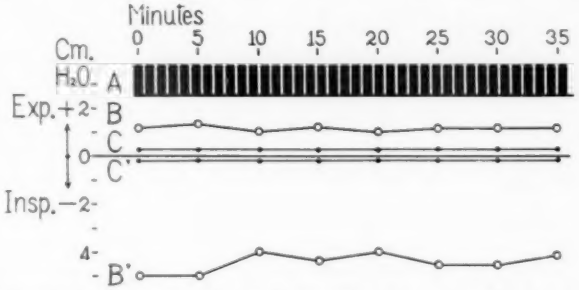

Fig. 8.—Simple inspiratory, lobular obstruction (see plan, fig. 2, *B*). Obstruction and observations were begun at the height of an expiration (no tidal air in the obstructed part). Intrapleural pressures are omitted. The designations are otherwise the same as in figure 5.

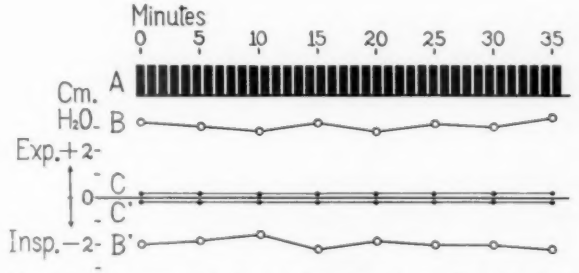

Fig. 9.—Simple expiratory, lobular obstruction (see plan, fig. 2, *C*). Obstruction and observations were begun at the height of an expiration (no tidal air in the obstructed part). Intrapleural pressures are omitted. The designations are otherwise the same as in figure 6.

the lung) with each inspiration throughout. The dog was killed. Autopsy showed that the obstructed part of the lobe was normally inflated.

COUGHING

A. Obstruction: Lobar and Total (Fig. 2, *D*).—Begun After Death; Tracheal Outlet Closed Completely About Bronchial Cannulas: From figure 10, *a*, it is seen that the distal pressure was 0 cm. of water; the proximal pressure, 0 cm.; the intrapleural pressure, —4.6

cm. The walls of the chest were squeezed together manually with moderate force. The distal pressure was 6 cm. of water; the proximal pressure 6 cm.; the intrapleural pressure, 1.3 cm. The walls of the chest were then released. The pressures returned approximately to the original values. The tracheal outlet was opened.

Five Cubic Centimeters of Air Injected into Dilatable Cannula (Into Obstructed Lobes); Tracheal Outlet Closed: From figure 10, *b*, it is seen that the distal pressure was 2 cm. of water; the proximal pressure, 0 cm.; the intrapleural pressure, —4.5 cm. The walls of the chest were squeezed together. The distal pressure was 10 cm. of water; the proximal pressure, 7.6 cm.; the intrapleural pressure, 5 cm. The walls of the chest were then released. The pressures returned approximately

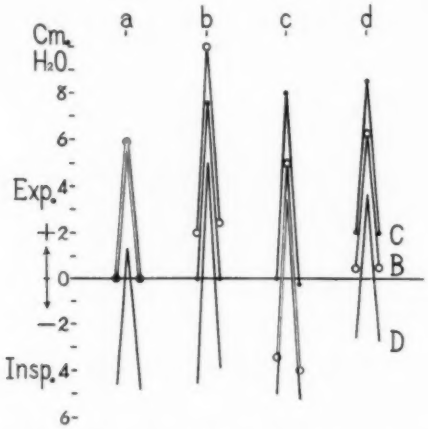

Fig. 10.—Total, lobar obstruction (see plan, fig. 2, *D*), instituted immediately after death. *B* indicates intrabronchial pressure distal to obstruction; *C*, this pressure proximal to obstruction; *D*, intrapleural pressure; *a*, period with obstruction and observations begun with the lung inflated as at death; *b*, period, begun after tidal air had been injected into the obstructed part of the lung; *c*, period, begun after tidal air and a part of residual air had been aspirated from the obstructed part; *d*, period, begun with the obstructed part inflated as at death and after tidal air had been injected into the free part of the lung. In each period there were three readings, the first without other manipulation, the second with the chest squeezed, and the third, again, without that manipulation.

to the original values. Added air was removed from the dilatable cannula. The tracheal outlet was opened.

Five Cubic Centimeters of Air Aspirated from Dilatable Cannula (From Obstructed Lobes): Figure 10, *c*, shows that the distal pressure was —3.4 cm. of water; the proximal pressure, 0 cm.; the intrapleural pressure, —5 cm. The walls of the chest were squeezed together. The distal pressure was, 5 cm. of water; the proximal pressure, 8 cm.;

the intrapleural pressure, 3.4 cm. The walls of the chest were then released. The pressures returned approximately to the original values. Subtracted air was returned into the dilatable cannula. The tracheal outlet was opened.

Tracheal Outlet Closed; Fifteen Cubic Centimeters of Air Injected into Nondilatable Cannula (Into Nonobstructed Lobes): From figure 10, *d*, it is seen that the distal pressure was 0.4 cm. of water; the proximal pressure, 2 cm.; the intrapleural pressure, 2.6 cm. The walls of the chest were squeezed together. The distal pressure was 6.2 cm. of water; the proximal pressure, 8.5 cm.; the intrapleural pressure, 3.6 cm. The walls of the chest were released. The pressures returned approximately to the original values.

B. Obstruction: Lobar and Total (Fig. 2, *D*).—Begun at Height of Expiration; Living Dog; Tambours Replacing Bronchial Manometers (Kymographic Tracings Observed): It is seen in figure 11,

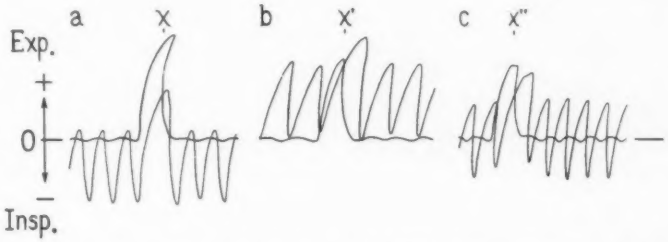

Fig. 11.—Kymographic tracings in total, lobar obstruction. *O* indicates the level of atmospheric pressure. Curves that oscillate widely and constantly represent the intrabronchial pressure distal to the obstruction. Other curves represent the intrabronchial pressure proximal to the obstruction. Intrapleural pressure is omitted. *a* indicates the period with obstruction begun at the height of an expiration (no tidal air in the obstructed part); *b*, period with obstruction begun at the height of an inspiration (tidal air included); *c*, period with obstruction begun at the middle of an expiration (one half of tidal air included); *x*, *x'* and *x.x''*, single coughs.

a, that at first the distal pressure oscillated regularly with respiration, the expiratory level lying slightly above atmospheric pressure and the inspiratory level lying markedly below that pressure; the proximal pressure oscillated similarly but very slightly at atmospheric pressure. One cough was produced at the fourth breath. Both pressures rose together sharply to much higher levels than before, the proximal pressure higher than the distal pressure, and they fell immediately to the original levels and oscillated as before. The obstruction was released.

Obstruction Begun at Height of Inspiration: Figure 11, *b*, shows that at first the distal pressure oscillated with respiration, the expiratory level lying markedly above atmospheric pressure and the inspiratory level lying at that pressure; proximal pressure oscillated very slightly at

atmospheric pressure. One cough was produced at the third breath. Both pressures rose together sharply to higher levels than before, the distal pressure higher than the proximal pressure, and they fell immediately to the original levels and oscillated as before. The obstruction was released.

Obstruction Begun at Midpoint Between Heights of Inspiration and Expiration: It is seen from figure 11, c, that at first the distal pressure oscillated, the expiratory and inspiratory levels lying equidistant from the atmospheric pressure; the proximal pressure, very slightly at atmospheric pressure. One cough was produced at the third breath. Both pressures rose together sharply to higher levels than before, about equal in elevation, and they fell immediately to the original levels and oscillated as before.

Circumstances Unaltered; Cough Produced at Every Breath, Kymograph Moving Rapidly: Figure 12 shows that at the beginning of the first cough (*a*, height of inspiration) the distal pressure was at a

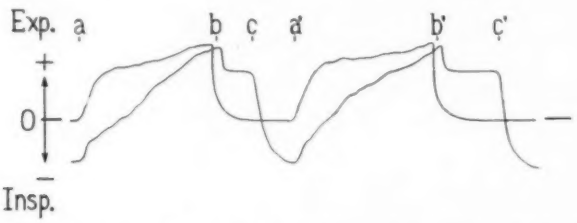

Fig. 12.—Kymographic tracings in total, lobar obstruction, obtained during two successive coughs and with the kymograph moving rapidly. *O* indicates the level of the atmospheric pressure. The curve that begins lower represents the intrabronchial pressure distal to the obstruction. The other curve represents the intrabronchial pressure proximal to the obstruction. *a* to *c* indicates the period of the first cough; *a'* to *c'*, period of the second cough; *a* to *b* and *a'* to *b'*, first phase of cough (tracheal outlet closed); *b* to *c* and *b'* to *c'*, second phase of cough (tracheal outlet open); *c* to *a'*, inspiration between the coughs.

moderate distance below atmospheric pressure; the proximal pressure, at atmospheric pressure. At this time the tracheal outlet was closed for two-thirds the expiration (*a* to *b*, first phase of cough), and both pressures rose rapidly to levels markedly above atmospheric pressure, about equal in elevation. The tracheal outlet was opened for the remainder of expiration (*b* to *c*, second phase of cough), and both pressures fell, the distal pressure slightly and the proximal pressure markedly and completely to its original level. At the end of the first cough (*c*, height of expiration) the distal pressure began to fall, and the fall continued throughout the following inspiration (*c* to *a'*) until it reached the original level. The second cough (*a'* to *c'*) showed the same type of behavior of the pressure.

C. Obstruction: Lobar and Simple Inspiratory (Fig. 2, *E*).—Begun at Height of Expiration (Observed Twenty-five Minutes): It is seen from figure 13 that at first the distal pressure at expiration was 0.2 cm. of water; the proximal pressure was 0.1 cm. (Only these pressures are important here.) There was no change for five minutes. No bubbling occurred at the valve. One cough was produced (*a*). The distal pressure rose sharply to 3 cm. of water; the proximal pressure, to 6 cm. There was a very slight bubbling of air (leaving the lung). The distal pressure fell immediately to 0.1 cm. of water; the proximal pressure to 0.1 cm. There was no change for two min-

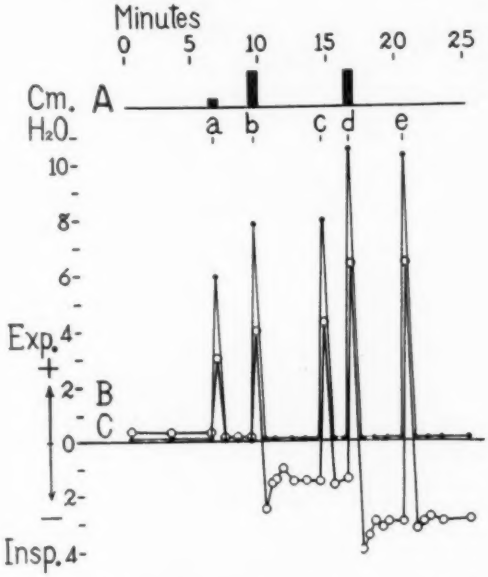

Fig. 13.—Simple inspiratory, lobar obstruction (see plan, fig. 2, *E*). *0 cm. H_2O* indicates the level of atmospheric pressure; *A*, columns representing approximately the amounts of air expelled through the valve at each expiration; *B*, curve representing the expiratory limit of the range of oscillation of the intrabronchial pressure distal to the obstruction; *C*, the same type of curve for the intrabronchial pressure proximal to the obstruction; *a*, *b*, *c*, *d* and *e*, single coughs of various intensities.

utes and no bubbling. One harder cough was produced (*b*). The distal pressure rose to 4 cm. of water; the proximal pressure to 7.8 cm. Air bubbled heavily. The distal pressure fell to —2.4 cm. of water; the proximal pressure to 0.1 cm. The distal pressure then rose gradually to —1.2 cm. and remained stationary for two minutes. There was no bubbling. One cough was produced (*c*), equal in force to the last. The distal pressure rose to 4.3 cm. of water; the proximal pressure, to 8 cm. There was no bubbling. The pressures

fell to previous levels. One harder cough was produced (*d*). The distal pressure rose to 6.4 cm. of water; the proximal pressure, to 10.6 cm. Air bubbled heavily. The distal pressure fell to —4 cm. of water, the proximal pressure, to 0.1 cm. The distal pressure rose gradually to —3 cm. in three minutes. There was no bubbling. One cough was produced (*c*), equal in force to the last. The distal pressure rose to 6.6 cm. of water; the proximal pressure, to 10.6 cm. There was no bubbling. The pressures fell to previous levels. (Further coughs, maximum in force and equal to the last two, caused no bubbling and no further depression of the distal pressure.)

D. Obstruction: Lobar and Simple Expiratory (Fig. 2, *F*).—Begun at Height of Expiration (Observed Seventy Minutes): It is seen from figure 14 that at first the distal pressure at expiration was

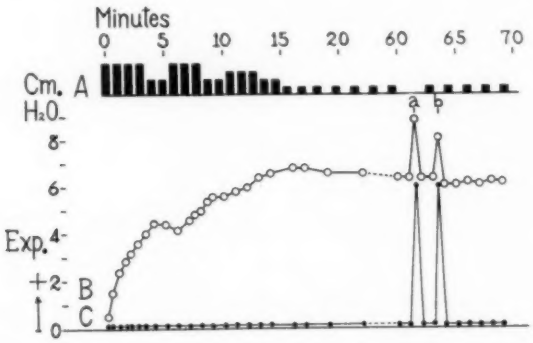

Fig. 14.—Simple expiratory, lobar obstruction (see plan, fig. 2, *F*). *A* indicates the columns representing approximately the amounts of air received through the valve at each inspiration; *a* and *b*, single coughs of different intensities. The designations are otherwise the same as in figure 13.

0.4 cm. of water; the proximal pressure, 0.1 cm. (Only these pressures are important here.) With every inspiration for four minutes air bubbled heavily at the valve (entering the lung), and the distal pressure rose steadily to 4.4 cm. Bubbling was then slightly less for ten minutes, and the distal pressure rose more gradually to 6.8 cm. After that, bubbling was still less and occurred only at every third or fourth inspiration, and the pressure showed no important change, in sixty minutes. The proximal pressure showed no change throughout. One cough was produced (*a*). The distal pressure rose sharply to 9 cm. of water; the proximal pressure, to 6 cm. There was no bubbling The pressures fell immediately to the previous levels. Another cough was produced (*b*), with the same effects. The conditions continued as they were before coughing.

E. Obstruction: Lobular and Total (Fig. 2, *A*).—Begun at Height of Expiration (Observed Twenty-five Minutes): It is seen in figure 15 that at first the distal pressure at expiration was 1.6 cm. of water; the proximal pressure, 0.1 cm. (Only these pressures are important here.) There was no important change for eighteen minutes. One cough was produced (*a*). The distal pressure rose sharply to 5.8 cm. of water; the proximal pressure, to 7 cm. The pressures fell immediately to the previous levels. Two other coughs were produced (*b* and *c*), with the same effects. The conditions continued as they were before coughing.

F. Obstruction: Lobular and Simple Inspiratory (Fig. 2, *B*).—Begun at Height of Expiration (Observed Twenty-five Minutes): Figure 16 shows that at first the distal pressure at expiration was 1.2 cm. of water; the proximal pressure, 0.1 cm. (Only these pressures

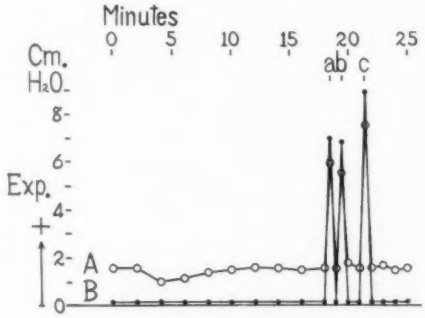

Fig. 15.—Total, lobular obstruction (see plan, fig. 2, *A*). *a*, *b* and *c* indicate single coughs of various intensities. The designations are the same as in figure 13.

are important here.) There was no important change for fifteen minutes. Air bubbled heavily at the valve (leaving the lung) with each expiration throughout. One very forceful cough was produced (*a*). The distal pressure rose sharply to 12 cm. of water; the proximal pressure, to 14 cm. Air bubbled unusually heavily. The pressures fell immediately to the previous levels. One harder cough was produced (*b*). Pressures rose a little higher and a little more bubbling occurred than with the first cough. They returned to the previous levels and remained there.

G. Obstruction: Lobular and Simple Expiratory (Fig. 2, *C*).—Begun at Height of Expiration (Observed Twenty-seven Minutes): Figure 17 shows that at first the distal pressure at expiration was 3 cm. of water; the proximal pressure, 0.3 cm. (Only these pressures are important here.) There was no important change for eighteen minutes. Air bubbled heavily at the valve (entering the lung) with each

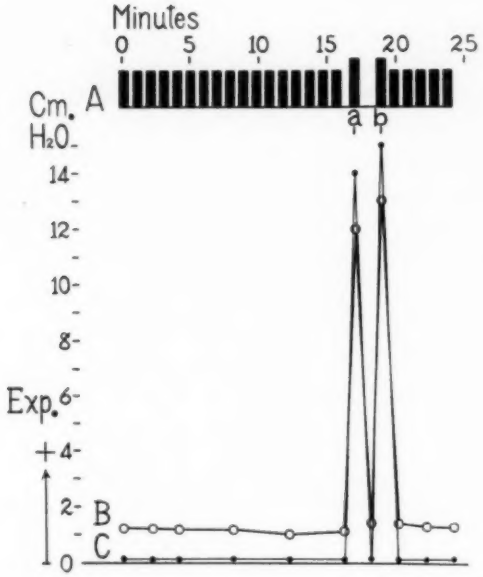

Fig. 16.—Simple inspiratory, lobular obstruction (see plan, fig. 2, *B*). *a* and *b* indicate single coughs, consecutive and very intense. The designations are otherwise the same as in figure 14.

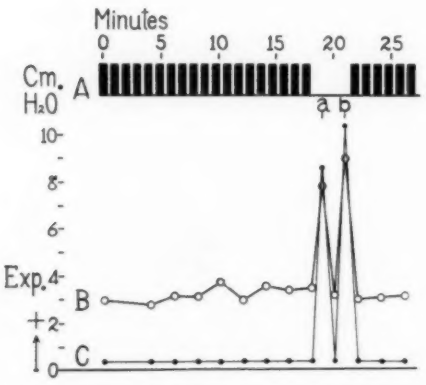

Fig. 17.—Simple expiratory, lobular obstruction (see plan, fig. 2, *C*). Single coughs of different intensities are indicated by *a* and *b*. The designations are the same as in figure 14.

inspiration throughout. One cough was produced (*a*). The distal pressure rose sharply to 8 cm. of water; the proximal pressure to 8.6 cm. There was no bubbling. The pressures fell immediately to the previous levels. One harder cough was produced (*b*). The pressures rose a little higher than with the first cough. They returned to the previous levels and remained there, and bubbling occurred as before coughing.

CONCLUSIONS

FREE BREATHING

In all varieties of bronchial obstruction the intrabronchial pressure distal to the point of obstruction oscillates with respiration about the level of atmospheric pressure, rising above it in expiration and falling below it in inspiration. The intrabronchial pressure proximal to the obstruction oscillates in a similar manner but much less widely. Accordingly, at expiration the distal pressure is higher than the proximal pressure, and at inspiration the relationship is reversed. The deeper the respirations are, the greater are the oscillations of the distal pressure and the greater the differences between the two pressures. The zone of oscillation of the distal pressure shifts up and down on the scale of pressures with increases and decreases in the degree of inflation of the obstructed part of the lung. Thus, if the obstructed part contains tidal air (obstruction begun at height of inspiration), the zone lies high, with the expiratory pressure extending markedly above the atmospheric level and the inspiratory pressure falling only slightly below that level; if tidal air is partly, or entirely, missing (obstruction begun during expiration or at its height), the zone is lower and the expiratory pressure is only slightly above the atmospheric level; and if all of the tidal air and part of the residual air are lacking (absorbed after obstruction), the zone is still lower and lies entirely below atmospheric pressure. The intrapleural pressure oscillates with respiration in the same manner and to about the same extent as the distal intrabronchial pressure but at much lower and subatmospheric pressures. These pressures present, also, certain special forms of behavior which are characteristic of the various types and positions of bronchial obstruction. Different forms of behavior occur because the obstructed and free parts of the lung develop different conditions of inflation. The obstructed part becomes differently inflated in all forms of bronchial obstruction, because air enters or leaves the obstructed part with reduced facility. In those forms of obstruction in which the air tends to be absorbed without being constantly replenished the differences of inflation are particularly great. The special forms of behavior are as follows:

In total, lobar bronchial obstruction the zone of oscillation of the distal intrabronchial pressure changes only as a result of absorption

of the air. If the zone is high to begin with (tidal air included) it starts to fall very soon and within a few minutes it comes to rest at a level with the expiratory pressure slightly above atmospheric pressure (characteristic position when tidal air alone is lacking).[15] This level may be maintained for several hours. If the zone is low to begin with (tidal air excluded), it suffers no change for several hours.[16]

In simple inspiratory, lobar obstruction any tidal air that may be included in the obstructed part of the lung to begin with escapes quickly past the valve, and the zone of oscillation of the distal intrabronchial pressure falls in pace with the loss of air. When that air is gone, no more passes the valve and the obstruction becomes total in effect, with the pressure levels stationary, as described in the preceding paragraph. The obstructed part is not collapsed by the action of the valve.

In simple expiratory, lobar obstruction air enters rapidly through the valve, until the obstructed part has reached its capacity for air, and then only a little enters from time to time.[17] The zone of oscillation of the distal intrabronchial pressure rises in pace with the accumulation of air, and when the capacity for air is reached, the zone remains stationary. The expiratory limit of the zone may reach nearly any height, depending on the degree of expiratory effort; and the inspiratory limit may rise above atmospheric pressure. The thoracic parietes expand automatically to accommodate the inflated parenchyma and to maintain the original range of respiratory movement. The intrapleural pressure is thus kept unchanged. As additional evidence of this automatic accommodation is the fact that, if the animal is killed at this time, both the distal intrabronchial and the intrapleural pressures rise markedly. The obstructed part is emphysematous.

In the three types of lobular obstruction collateral respiration saves the obstructed part of the lung from such alterations of inflation as develop in lobar obstruction. Accordingly, if the obstruction is valvular, air enters or leaves by the valve (depending on the type of valve) with every respiration for indefinitely long periods, and escape or supply

15. The fall in pressure is probably due to the absorption of tidal air from the obstructed part of the lung. The stationary condition after that is interpreted as indicating an extremely slow absorption of the residual air, or no absorption at all, for the time being. Other work (Van Allen, Lindskog and Richter [footnote 8, first reference]) has shown that when the residual air is absorbed and atelectasis is produced, the distal intrabronchial pressure falls markedly below atmospheric pressure. The intrapleural pressure falls markedly also (Elkin, D.: Ann. Surg. **86**:885, 1927, and previous reference).

16. Four hours was the longest period of observation of these pressures.

17. This is apparently only just enough to make up for absorption.

of air by collateral connections proceeds concurrently, so that the pulmonary inflation and pressures stay the same.[18] The obstructed part becomes neither collapsed nor emphysematous.

COUGHING

Cough is accomplished during expiration and has two phases.[19] The first phase begins with the onset of effort to expire. The tracheal passage is blocked completely (by adduction of the vocal cords in natural cough and by artificially applied occlusion of the tracheal outlet in these experiments) and the intrabronchial and intrapleural pressures rise sharply. The second phase begins after a moment with sudden opening of the trachea. The imprisoned air escapes explosively, and the intrabronchial and intrapleural pressures fall. The height to which the pressures rise in the first phase is in proportion to the inflation of the lung as a whole to begin with and to the expiratory effort. In general, the principles that have been described for free breathing apply also to cough, as follows: The object obstructing the bronchus lies between two pressures of air during cough, the relationship between which is determined by the relationship between the inflations of the obstructed and free parts of the lung. These relationships may be changed, even reversed, at any instant in cough. Since the direction in which the intrabronchial impulses tend to displace the obstruction must be that of the action of the greater impulse and the force is the difference between the two impulses, the displacing influence of cough is variable as to both direction and force, even with a constant degree of expiratory effort. In succeeding paragraphs are given the relationships between the inflations of the two parts of the lung and the directions of the displacement that the obstruction may undergo in the two phases of cough, for the varieties of bronchial obstruction.

In total, lobar obstruction the inflation of the obstructed part during the first phase of cough may be the same or less than that of the free part, depending on whether or not tidal air is contained in the obstructed part at the onset of the act. According to this circumstance, then, there is no displacing impulse or there is one directed toward the alveoli. During the second phase, as air is discharged from

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18. Other work (Van Allen and Adams [footnote 7]; Van Allen, Lindskog and Richter [footnote 8, first reference]; Van Allen and Lindskog [footnote 8, third reference]; Adams [footnote 10]) has shown that the absorption of air from the obstructed lobules is also compensated for by collateral respiration.

19. It seems more logical to describe cough as confined entirely to expiration, rather than to include the preceding inspiration as the first phase of the act, as is commonly done. Indeed, cough may be accomplished with all its essential effects from a state of respiratory rest and without any additional preliminary inflation of the lung.

the free part and the inflation of that part falls, the relationship between the inflations changes rapidly. Thus, if the obstructed part contains tidal air in any amount at all at the beginning of the cough, its inflation quickly becomes the greater and a displacing impulse develops which is directed toward the trachea. If the obstructed part has no tidal air but has a full amount of residual air at the beginning of the cough, its inflation quickly becomes equal to that of the free part and there is no displacing impulse. If, finally, the tidal, and a part, or all, of the residual air is missing from the obstructed part, its inflation remains the lesser, and there is a displacing impulse directed toward the alveoli.

In simple inspiratory, lobar obstruction the obstructed part rapidly discharges any tidal air that it may contain, and its inflation becomes and remains less than that of the free part (except at the end of the second phase of cough when tidal air is entirely lost also from the free part and the inflations become the same). Throughout the act, then, there is a displacing impulse directed toward the alveoli.

In simple expiratory, lobar obstruction the obstructed part rapidly gathers tidal air, and its inflation becomes and remains the greater. Throughout the cough, then, there is a displacing impulse directed toward the trachea.

In the three types of lobular obstruction the obstructed part receives and gives off air with respiration (either by collateral respiration alone or both by that means and by valve), but less freely than does the free part. During the first phase of cough the inflation of the obstructed part is slightly the lesser and there is a displacing impulse directed toward the alveoli. In the second phase the inflation of the obstructed part quickly becomes the greater, and there is a displacing impulse directed toward the trachea.

COMMENT

A type of bronchial obstruction which is not referred to is one in which the bronchial lumen is incompletely occluded during both periods of respiration. It occurs spontaneously in clinical patients from the presence of a small mass of viscid mucus or inspissated pus on the wall of a bronchus, from a neoplasm partially filling or compressing a bronchus, or from an inflammatory swelling of the bronchial wall.[6] The aerodynamics of this type of obstruction was investigated, but description of the experiments and the results are not given, because the subject was found to be so simple as not to warrant separate detailed presentation. The method was the same in principle as that used for the other work, except that the dilatable cannula was replaced by one that only partially filled the bronchus. The aerodynamics of partial bronchial obstruction was found not to be influenced by the factors—

position of obstruction, absorption of air and collateral respiration—that may affect total and valvular forms of obstruction. Air passed the obstruction at each period of respiration but with somewhat less facility than through the normal bronchial passage. Accordingly, the intrabronchial pressure distal to the obstruction in expiration was greater than that proximal to it, and in inspiration it was less. The differences in the two pressures were in proportion to the extent of the obstruction, and to the depth of breathing, but they were not so great as in total obstruction. Cough invariably produced an impulse with a tendency to drive the obstruction toward the trachea, and this occurred during the second phase of the act.

In many essential respects the aerodynamics of bronchial obstruction depends on the simple anatomic fact that the passages on both sides of the obstruction communicate directly with, and receive air from, parts of the lung, and on the principle arising from this fact, that the pressures in the passages proximal and distal to the obstruction have the same relationship to each other as the inflations of the parts of the lung proximal and distal to the obstruction. The period and the force of respiration do not primarily determine these pressure relationships. Bronchial obstruction is thus differentiated from tracheal, laryngeal and upper respiratory obstruction, for in the latter the lung lies entirely on one (the distal) side and the pressure on that side alone may be expected to change with respiration. There, the distal pressure is necessarily the greater at expiration and the proximal pressure (atmospheric pressure) is the greater at inspiration. It is to be noted that the conditions of bronchial obstruction in the experiments held to the anatomic circumstance mentioned, for the passage on one side of the obstruction led to the occluded part of the lung and that on the other side to the free part.

The problem referred to at the beginning of the paper, namely, the inconstancy of the effects of cough on substances contained in the bronchi, can now be better understood. The experiments show that alterations of the direction of the cough impulse may take place at nearly any instant during cough and from cough to cough. The influences that determine the direction of the impulse are not such as to be disclosed at ordinary bedside or fluoroscopic examination of the chest, and to the clinical observer the effects may well appear to be inconsistent. A point to be kept in mind concerning the action of cough is that it depends for aerodynamic eliminative effect on the presence of tidal air in some quantity in the lung distal to the obstruction. Just as the cough produces no external explosion when the lung as a whole contains no tidal air, so also cough obtains no explosion from a single bronchus unless the part of the lung supplied by that bronchus contains tidal air.

The results of the experiments furnish an answer as well to the other problem, as to whether an object obstructing a bronchus may produce atelectasis by acting as a valve and discharging the imprisoned air. Atelectasis cannot be produced in this way, under the natural conditions of bronchial obstruction. The object may, indeed, act as a valve, but it discharges air only as long as tidal air remains in the obstructed part of the lung, which is for a period of a breath or so at the most in lobar obstruction and for an indefinitely long period (while collateral respiration continues to supply the part with tidal air) in lobular obstruction. The development of atelectasis is hastened to the extent that the tidal air is eliminated, but it must await removal of the residual air by the slower process of absorption. Those who favor the theory of exhaustion of air by valvular action suggest that the residual air is "milked" past the valve. They point out that the obstructed segment of lung must be pressed on from the sides by the free and fully inflated portions when the individual makes effort to expire. The present experiments showed, to be sure, that the obstructed part is so pressed on and that the pressure in the passages distal to the obstruction is raised thereby, but they showed, too, that this cannot expel the residual air through the valve, because pressure is being exerted at the same time on the proximal side of the valve. The fact is that the pressure obtained on the proximal side of the valve is greater than that on the distal side. This is so regardless of how great the effort to expire may be (tidal air being absent from the obstructed part of the lung). Only when the natural anatomic relationships of the bronchi, just referred to, have been altered, may the residual air be "milked" past the valve. This occurred in the original experiment of Van Allen and Adams with a water valve, for the proximal side of the valve was given no connection with the free part of the bronchial tree. When the animal strained to expire with each breath, the pressure on the proximal side (atmospheric pressure) remained constant, the pressure on the distal side was raised, and the residual air was expelled. An artificiality with the same effect was probably present, also, during the bronchoscopic observations of Jackson referred to. The bronchoscope acted as a cannula. It reached into the obstructed bronchus, separating it to some extent from the other bronchi and connecting the outer face of the valvular obstruction directly with the outside. Its presence in the larynx and trachea probably interfered somewhat with the respiration of the free parts of the lung. Accordingly, when the individual strained to expire, the pressure on the distal side of the valve at expiration may well have been higher than that (atmospheric pressure) on the proximal side, the result of which would be to expel some of the residual air through the valve with every breath. One infers from Jackson's descriptions of the valves that

some of them at least were situated in large lobular bronchi; and in these cases another explanation suffices. In lobular obstruction under any of the circumstances valvular action may continue indefinitely; however, without producing atelectasis.

The condition that Jackson and Lee [20] described clinically and termed obstructive emphysema was reproduced experimentally in this work for the first time. As was noted in their patients, so also in these animals, the condition depended on the presence of a valvular type of obstruction in a bronchus, with the effect of allowing the obstructed part to inspire only. Air accumulated faster than it could be absorbed, and the parenchyma became overdistended. One contribution to the subject was made here, for it was found that obstructive emphysema occurred only in lobar obstruction. When the bronchus of a group of lobules alone within a lobe was obstructed with a valve of this type, collateral respiration removed the air as fast as it entered through the valve and prevented overinflation of the parenchyma.[21]

Lobular obstruction undoubtedly occurs much more frequently than lobar obstruction. A drop of moisture in a capillary respiratory duct must fill the lumen over a considerable length and prevent the passage of air, so that obstruction of this magnitude, at least, probably occurs in most cases of bronchial catarrh. When cough or other expiratory effort takes place right away, the tidal air originally imprisoned must still be present to serve for elimination of the obstruction; but when the subject sleeps or for other reasons remains quiet for a period, absorption proceeds and collateral respiration may compensate for it and maintain a supply of tidal air for the eliminative action of cough when rest ceases. It is, therefore, likely that collateral respiration is important in pulmonary economy. A bronchial tree without provision for collateral respiration would be as inefficient as a blood-vascular system without collateral circulation, perhaps more so since bronchial obstruction is probably more common than arterial obstruction.

It should be remembered that cough appears to have other means of effecting or promoting broncho-elimination than the action of the intrapulmonary currents of air, at least as far as the larger bronchi are concerned. The walls of the larger bronchi contract with expiration and dilate with inspiration. The movements become very marked with vigorous breathing. We have seen in dogs by bronchoscopy that the lumina of tertiary bronchi become totally obliterated when the animals strain to expire, and the same effect has been observed in man.[22] It seems probable that these movements aid broncho-elimina-

20. Jackson, C., and Lee, W.: Tr. Am. S. A. **43**:723, 1925.

21. It is conceivable that obstructive emphysema might occur in a lobule alone, but this would have to be under conditions with interference to collateral respiration.

22. Weingaertner, M.: Arch. f. Laryng. u. Rhin. **32**:1, 1920.

tion, the contraction first serving to mold any soft plastic mass that lies in the bronchus and to squeeze it along the passage, and the dilation then permitting air to be inspired past the mass. Tidal air would thus be provided to the obstructed part of the lung, and subsequent coughing would be rendered more productive. The deep breathing that is advocated clinically for relief from bronchial obstruction obtains the result only in this manner, it would seem, when a lobar bronchus is obstructed; but when a lobular bronchus is affected, both this mechanism and that of collateral respiration may be called into operation to bring air to the affected part. Indeed, as regards the action of collateral respiration, experiments [23] have shown that deep breathing markedly increases the rate of transmission of air to and from obstructed lobules. The transmission has been found to cease altogether in very shallow breathing.

SUMMARY

The principles of behavior of the intrapulmonary pressures and currents of air in bronchial obstruction were investigated in a series of experiments. The various types and positions of obstruction that have been described in man and the forms of breathing that accompany them were reproduced in dogs, and the air pressures and currents were measured and observed directly. The behavior was found to be consistent and to follow certain rules, so that principles of aerodynamics of bronchial obstruction were formulated. Of particular interest was the difference that was found between the aerodynamics of lobar and lobular obstructions. Collateral respiration was found to be responsible for this difference. The results of the study also afforded clarification for certain obscure clinical phenomena of bronchial obstruction, particularly for the inconstant effects of cough on materials occluding the bronchi and for the relationship between valvular bronchial obstruction and atelectasis. The clinical condition of obstructive emphysema was reproduced experimentally, and knowledge of its nature was advanced.

23. Van Allen, Lindskog and Richter (footnote 8, fourth reference).

SO-CALLED FIBROSARCOMA OF BONE

BONE INVOLVEMENT BY SARCOMA OF THE NEIGHBORING SOFT PARTS *

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The osteogenic portions of the bone do not give rise to sarcoma of the true fibrospindle cell type, the connective tissue tumors arising in this structure being either fibroblasts of the fibro-osseous series with a tendency to true bone formation (fig. 1) or precartilaginous connective tissue destined to form bone via the intracartilaginous route (fig. 2) (Geschickter [1]). Fibrospindle cell sarcoma arising in either the outer layers of the periosteum or in the adjacent soft parts may, however, invade the osseous substance and give rise to a tumor in which the predominant manifestations on physical or roentgenologic examination are related to the bone. Such bone involvement, by direct extension from the soft parts, is clinically very confusing, particularly when the bone changes are extensive, and even at operation or after pathologic examination of the tissue, is usually misinterpreted as a primarily osseous lesion.

While from a pathologic standpoint this group of tumors usually has a structure indicating a connective tissue origin, the current conception that these fibrosarcomas that invade the bone are all products of the nonosteogenic layers of the periosteum is erroneous. These tumors, on the contrary, are far more variable in origin and may arise either from this investing portion of the periosteum or from a similar connective tissue or fascia, investing muscles, vessels or nerve trunks in the overlying soft parts. In fact, in the present series of fifty cases clinically grouped under the heading of fibrosarcoma of the bones, new growths with an origin in these various structures are all represented. The largest group of these neoplasms (thirty-one) show a histologic composition of fibroblasts, spindle cells or small oat-shaped cells, relating them to a single cycle of development in connective tissue concerned with the fibrous portions of the outer periosteum, the fascia or the fibrous portion of nerve trunks or vessels. This group, which may be

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* From the Surgical Pathological Laboratory of the Johns Hopkins Hospital and University.

1. Geschickter, C. F.: Fibrocartilaginous Tumors of Bone, Arch. Surg., to be published.

termed the fibrospindle cell series, is a true pathologic entity and may be graded in its malignancy according to the degree of differentiation shown by the predominating cells. A more varied and smaller group of these neoplasms must be differentiated from this larger fibrospindle cell series. In this small group, a careful analysis of the histologic structure shows the tumor to be arising from neurogenic elements

Fig. 1 (path. no. 36784).—Fibroblastic tissue in bone laying down osteoid spicules in response to a low grade infection. The fibroblasts are transforming into osteoblasts which are applied to the surface of bone newly formed from fibrous tissue.

(neurogenic sarcoma) or from the muscle (rhabdomyosarcoma) or probably from vessels (angioma), and hence the type of treatment and prognosis must be correspondingly different. This small and miscellaneous group of tumors, despite a varied source of origin, may secondarily implicate the bone because of a proximity to this structure.

The present study, therefore, is to show that the histologic composition in the new growth is a more reliable index to its clinical and pathologic behavior than is the anatomic location or apparent relationship to bone. Assumptions regarding prognosis or treatment based on proximity to bone disclosed by the x-rays or at exploration, or based on the gross resemblance of the neoplasm to a fibroid substance are

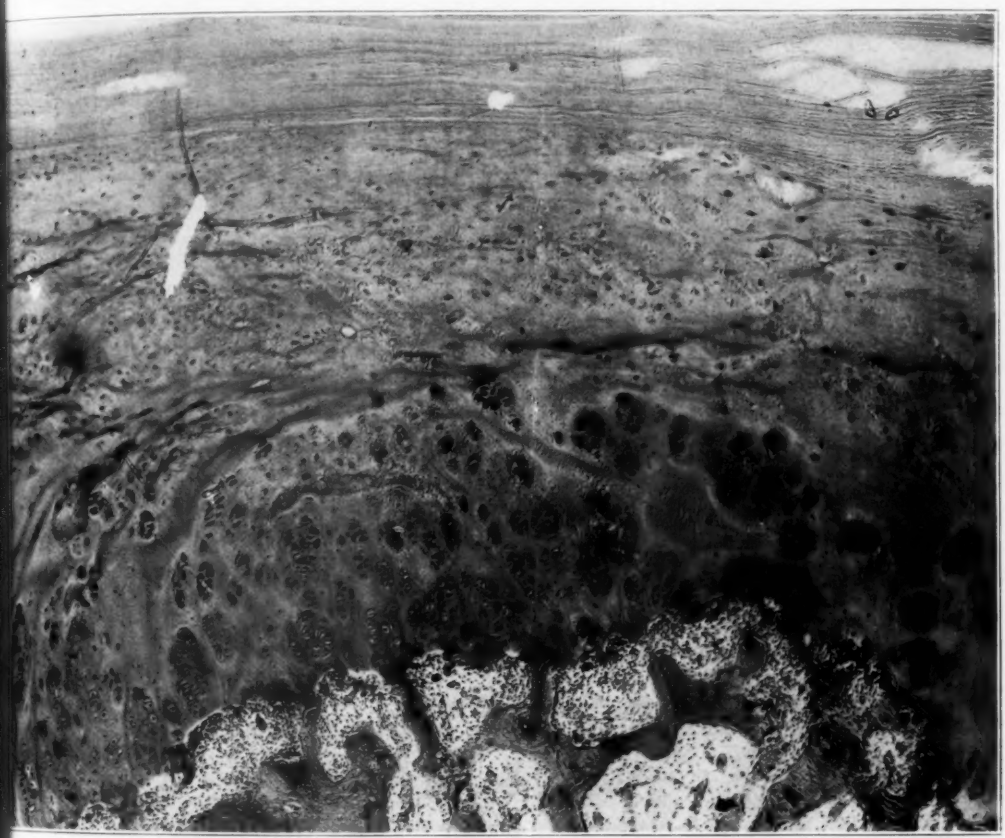

Fig. 2 (path. no. 26392).—Photomicrograph from an osteochondroma showing overlying strands of precartilaginous connective tissue transforming into cartilage which is undergoing calcification. This precartilaginous connective tissue is the mother substance responsible for the resulting osteochondroma.

untrustworthy in this group of neoplasms. But conclusions can be drawn with a fair degree of accuracy after microscopic examinations which permit the lesion to be classified in either the fibrospindle cell group, the neurogenic group or among tumors derived from other soft part structures, and which also allow of a definite grading according to the degree of cellular differentiation.

TUMORS OF THE FIBROSPINDLE CELL GROUP

Invasion of the bone from without, through direct extension by a tumor of nonosseous origin usually indicates the presence of a sarcoma of the fibrospindle cell group. Such bone involvement is of relatively infrequent occurrence and is recorded in this laboratory in only about 1.5 per cent of the cases among seventeen hundred neoplasms involving bone. The majority of the sarcomas in this group are not of a high degree of malignancy, and the life of the patient can usually be safeguarded if the proper diagnostic and therapeutic measures are carried out in time.

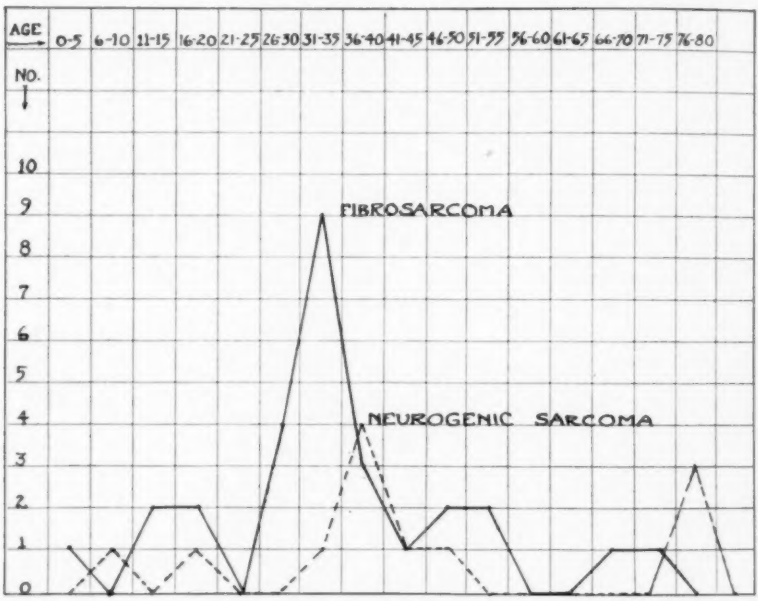

Fig. 3.—Chart showing the age incidence in thirty-eight cases of so-called fibrosarcoma of the bone. The solid line indicates the tumors of the fibrospindle cell series; the broken line, tumors of the neurogenic series.

Clinical Features.—Fibrospindle cell sarcoma is a disease of adult life, occurring most frequently beyond the age of 30. The age incidence is remarkable for a sarcomatous tumor and parallels more closely the distribution of carcinomas among adults. The lower extremity is usually the site of predilection, the region of the femur being most often involved. More rarely the upper extremity may be implicated, and in exceptional instances the new growth may overlie the skull or ribs or be found within the pelvis (figs. 3 and 4, tables 1 and 2). The patients thus affected give a history of a condition of about one year's duration beginning with pain of increasing severity and followed by the

appearance of swelling and then by dysfunction of the limb. In several instances a pathologic fracture occurred.

The swelling is smooth in contour and differs from the ordinary type of soft part sarcoma in the depth of its location and in its firm attachment to the underlying bone. Interference with function is also more rapid in the affected limb because of this proximity to bone. The tumor growth is fairly rapid and steadily progressive, producing a

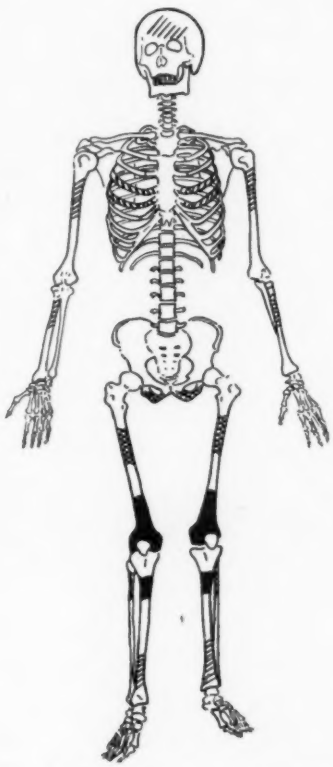

Fig. 4.—Chart showing skeletal distribution in thirty-eight cases of fibrosarcoma and neurogenic sarcoma of the bone. The black areas indicate the most frequent sites; the checked areas, the common sites and the diagonal lines, the rare or occasional sites.

mass of firm or rubbery consistency. When the swelling is situated near the end of a bone, the growth may extend across the joint and ultimately involve a neighboring bone, a type of invasion that is exceedingly rare in truly osteogenic tumors. Although the regional lymph nodes may be enlarged, metastases to the lymph glands has not been microscopically proved in these cases and probably does not occur.

TABLE 1.—*Differentiated Forms of Fibrospindle Cell Sarcoma*

Path. No.	Race	Sex*	Age	Location	Duration, Mo.	Symptoms	Roentgenologic Picture	Treatment	Microscopic Picture	Result
38182	W	♀	46	Femur	..	.....	Soft part shadow, some bone destruction	Amputation, July 14, 1926	Spindle cell	Well 9 mo.
37113	C	♀	20	Femur, upper	..	Pain, tumor	.....	Excision, April 6, 1925; radium	Fibrospindle cell	Well over 2 yr.
35750	W	♂	43	Tibia, upper	17	Pain	Soft part shadow, some secondary bone destruction	Curettement, Aug. 9, 1924; radium in wound	Fibrospindle cell	Dead 8 mo. following operation
35023	W	♀	30	Femur, lower	3	Tumor	Slight bone involvement	Excisions, 1914 and 1918; amputation, 1928	Spindle cell	Dead 10 yrs. following first excision
32906	...	..	33	Femur	12	Pain, swelling; 6 mo.	Secondary bone destruction	Exploration, Jan. 25, 1919; x-ray; radium, March 13, 1919	Fibrosarcoma	Well 11 yrs. following exploration
32897	C	♀	55	Humerus, upper	36	Pain, trauma, tumor	.....	Exploration, May 3, 1923	Fibrosarcoma	.....
31267	W	♀	34	Skull	2½	Slight pain, tumor	Secondary bone destruction	Exploration, Oct. 14, 1922	Spindle cell	Dead 5 yr. later
29401	W	♀	..	Leg (knee)	36	Trauma, tumor	Large soft part shadow	Amputation, Nov. 19, 1921; amputation following 2 excisions; x-ray and radium	Fibrospindle cell	Well 8 yr., 5 mo. later
29259	...	M	..	Ankle region	..	Tumor	Soft part shadow, secondary bone destruction	Exploration, April, 1917; radium, Oct. 1917; Coley's toxins; amputation	Fibrospindle cell	Well 13 yr. following first operation
28240	W	♂	40	Scapula	..	Tumor	Soft part shadow	Partial excision, April, 1920; x-ray	Spindle cell	Disease progressing (11 yr.)
28189	W	♀	33	Scapula	1	Tumor	.....	Excision, September 1920, excision of recurrence May 23, 1921; x-ray, radium	Fibrospindle cell	Well 3 yr. following second operation
27884	W	♀	33	Ribs, 5th and 6th	..	Tumor	.....	Excision, excision of recurrence, November, 1911; x-ray	Fibrospindle cell	Well nearly 10 yr. following second operation
27752	W	♀	34	Femur, lower	24	Tumor, pain limp, 1 yr.	.....	Exploration, Feb. 1, 1921; resection, Feb. 4, 1921	Fibrosarcoma	Dead 9 yr. following resection
27555	W	♂	49	Radius, lower	12	Tumor following 4 fractures	Periosteal shadow with bone destruction	Amputation, Sept. 24, 1920	Fibrospindle cell	Well 4 yr.
27347	W	♂	..	Femur, lower	12	Tumor	Extensive bone destruction	Radium, October, 1920; curettement; amputation for recurrence, Feb. 12, 1921	Spindle cell	Well over 9 yr. later
26884	W	♂	29	Fibula, shaft	12	Trauma, pain, tumor	Soft part shadow, some secondary bone destruction	Amputation advised	Fibrospindle cell	Dead 14 mo. following onset; (tuberculous pneumonia)
26877	W	♂	30	Tibia, upper	48	Intermittent pain	Periosteal shadow, some bone destruction	Exploration, January, 1917 (5 mo. following onset); gold therapy January, 1919; exploration, August, 1920; amputation, Nov. 22, 1920	Spindle cell	Well almost 9 yr. following amputation
25453	W	♂	53	Femur, lower	14	Pain, tumor	Lungs, normal; periosteal tumor mass; small amount bone destruction and bone formation	Amputation, Feb. 14, 1920	Fibrospindle cell	Well 6 yr. later
24536	W	♂	58	Femur, upper	17	Weakness, tumor	Soft part shadow, extension secondary bone destruction	Amputation, May 20, 1919	Spindle cell	Well over 8 yr.
23407	W	♀	29	Femur, lower	10	Trauma, tumor, dysfunction of knee	Soft part shadow, much secondary bone destruction	Amputation, July 5, 1918	Fibrosarcoma	Well almost 12 yr. later
15722	W	♂	12	Tibia, upper	3	Pain, swelling, tenderness	.....	Exploration, April 22, 1892; amputation, April 27, 1922	Spindle cell	Lost
Surg. No. 9203 (9606)	C	♂	19	Femur, lower	30	Trauma, joint of fusion; 2d trauma, pain; swelling	Soft part shadow, extensive bone destruction	Exploration, Sept. 2, 1908; subsequent resection	Spindle cell	Dead 11 yrs. later

Roentgenologic Features.—Fibrosarcoma affecting bone resembles other forms of sarcoma of the bone in its tendency to occur as a single lesion and to involve the regions of the lower end of the femur or upper end of the tibia. It differs from other malignant periosteal tumors in the size and character of its soft part shadow and in its tendency to destroy the bone from without, inwardly. The one constant feature in the roentgenogram is this extra-osseous soft part shadow which is

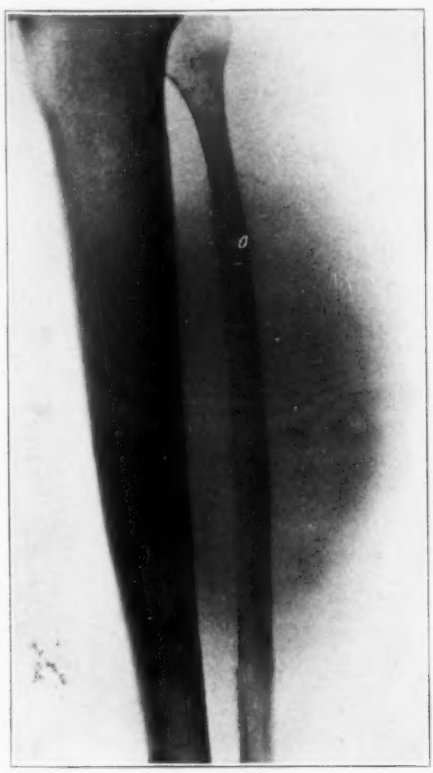

Fig 5 (path. no. 26884).—Roentgenogram of a typical case of fibrosarcoma involving the shaft of the fibula. There is a large soft part shadow, producing a faint periosteal reaction and splitting of the cortical layers of the bone. The patient was a white man, aged 29, giving a history of trauma, pain and tumor formation of twelve months' duration. Amputation was advised in this case. The patient died of a tuberculous pneumonia fourteen months after examination.

more opaque than the cartilaginous masses seen in periosteal chondrosarcoma and less dense than the true bone formation seen in osteogenic sarcomas.

The reaction of the underlying bone to the presence of the tumor is more variable. In the most easily recognized cases the bone is melted

away from without, inwardly with little or no periosteal reaction (figs. 5 and 6). In less typical cases strands of the periosteum which are split and raised may show varying degrees of ossification, but these are never dense or conspicuous (fig. 7). Calcification in the tumor substance is not the rule and is more typical of an aneurysm, an old abscess of the soft parts or of a rare chondroma associated with some bursa in the region of the joints. Occasionally, however, when the fibrous

Fig. 6 (path. no. 23407).—Anteroposterior and lateral views of a low grade of fibrosarcoma involving the lower end of the femur of a white woman, aged 29, who gave a history of trauma, tumor and dysfunction of ten months' duration. The patient is alive twelve years following a primary amputation. Note the large soft part shadow and the bone destruction resulting from invasion of the osseous substance from without. The microscopic structure of this tumor is shown in figure 22.

growth has become large and is not extremely rapid or after a course in deep roentgen therapy, a slight degree of calcareous stippling will be observed.

The size of the soft part tumor which exceeds the area of bone destruction is a helpful diagnostic point. Usually the extra-osseous shadow is large before much evidence of bone destruction is found. Occasionally, however, rarefaction and invasion of the marrow cavity is also pronounced so that there is a resemblance to metastatic carcinoma or osteolytic sarcoma of the osteogenic type (fig. 6). In such instances, however, the size of the soft part shadow, the disappearance of the cortex and the asymmetrical erosion of the marrow cavity gives evidence

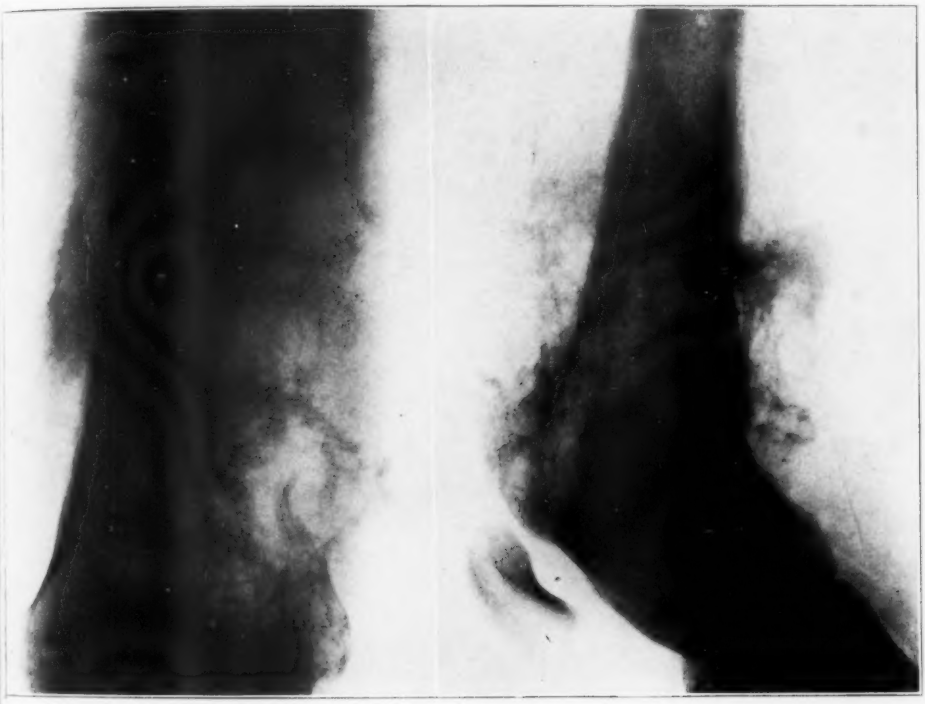

Fig. 7 (path. no. 25453).—Anteroposterior and lateral views of a fibrospindle cell sarcoma which is invading the bone. The soft part shadow has an unusual amount of calcified and osseous markings, most of which are due to the splitting and raising of the periosteum. The patient was a white man, aged 53, who had suffered with pain and tumor in the lower end of the femur for fourteen months. He has remained well over six years following the primary amputation.

that the bone is being destroyed from an external rather than an internal cause, as in the truly central lesions produced by metastatic carcinoma or the osteolytic variety of osteogenic sarcoma (figs. 8 and 9). Benign giant cell tumor and benign bone cyst should not be a source of confusion since these benign growths give evidence of their central origin by

expanding the shell of cortical bone from within and rarely produce a soft part tumor of any significant size.

Gross Specimens.—At operation, the tumor is generally found to be definitely encapsulated, although occasionally the fibrous tissue is found infiltrating muscle in the same manner in which it erodes and invades the bone. The tumor mass is firm and fibrous in consistency and often has the definite peculiarity of being arranged in whorls and strands

Fig. 8 (path. no. 37088).—A metastatic hypernephroma involving the shaft of the humerus. The area of bone destruction is central in origin and expands the cortex, which is undergoing destruction, symmetrically. There is little or no soft part shadow.

which run in a number of divergent directions. Occasionally the striation of the tumor is more regular (figs. 10 and 11), and in the more rapidly growing neoplasms the mass may be fleshy or colored with hemorrhagic material (figs. 12 and 13).

The kind and degree of bone involvement varies. In some instances the tumor mass may be shelled away from the bone, and the remaining

osseous surface may be cleaned readily with the knife. In other instances the cortex has disappeared, the cancellous substance is invaded and broken and the central portion of the bone involvement discolored by hemorrhage. In rare instances, when the tumor is relatively benign and slow in growth, the entire cortex is melted away, the marrow cavity invaded, but the neoplastic tissue is sharply demarcated from the firm reactive portions of the remaining bone (fig. 14).

Fig. 9 (path. no. 37614).—An osteolytic sarcoma in the lower half of the femur producing a central area of bone destruction followed by pathologic fracture and escape of the tumor into the soft parts. The extent of the soft part shadow is less than the area of bone destruction.

Dissection of the mass at operation, particularly when the tumor is large, does not often disclose the source of origin. In some instances it is clear that the relationship to the bone is secondary, the tumor shelling out easily and leaving a bare, denuded cortex with little or no evidence of osseous erosion. In other cases the association with the bone is more intimate. The tumor may be definitely attached to the periosteum and invade the cortex, gaining entrance to the marrow

cavity. On entering the marrow cavity it may penetrate up and down the long axis, splitting the bone and causing pathologic fracture. In such cases, the only evidence against a primary osseous origin is the extent to which the soft parts are involved in the region, the degree of extra-osseous involvement indicating that the tumor has had a beginning just without the bone and extended equally in both directions.

In some of the tumors involvement of the joint cavity, extension into adjoining bursae and into the neighboring muscles with involvement of the main nerve trunk or blood vessels suggests that the tumor is primarily of soft part origin.

Fig. 10 (path. no. 38182).—Gross specimen of a fibrosarcoma overlying and destroying the lower end of the femur in a white woman, aged 46, which was successfully amputated. The cut surface of the specimen shows clearly the interlacing fibrous bundles, characteristic of this type of fibrospindle cell sarcoma. The microscopic structure is shown in figure 21.

Microscopic.—Since fibrous tissue derived from an earlier form of connective tissue is common to nearly all organs of the body, the type of fibrospindle cell sarcoma invading bone that has such origin does not

differ histologically from similar tumors in many other locations. Fibrospindle cell sarcoma involving the joint capsule or ligaments, fibrous tumors arising from the outer vessel wall, and fibrosarcoma arising from the fascial planes in and about the muscles are a homogeneous group and differ in their fundamental pathologic process in no essential way from

Fig. 11 (path. no. 25453).—Specimen from the amputated leg in the case shown by roentgenogram in figure 7. The cut surface of the tumor shows clearly the definite fibrous capsule and the relationship to the underlying bone. The cortex is gradually being resorbed, and the tumor has found its way into the marrow cavity. Note the definite striations on the sectioned surface of the new growth, indicating a fibrous structure.

the fibrous new growths arising from the connective tissue framework of many of the internal organs.

It is possible, therefore, to treat these sarcomas of the fibrospindle cell group that secondarily involve the bone along with those arising

Fig. 12 (path. no. 24536).—Gross specimen of a small spindle cell tumor overlying the femur and invading the shaft of the bone in a white woman, aged 58. The patient has remained well over eight years following an amputation. The fleshy tumor is shown adherent to the periosteum of the shaft of the femur.

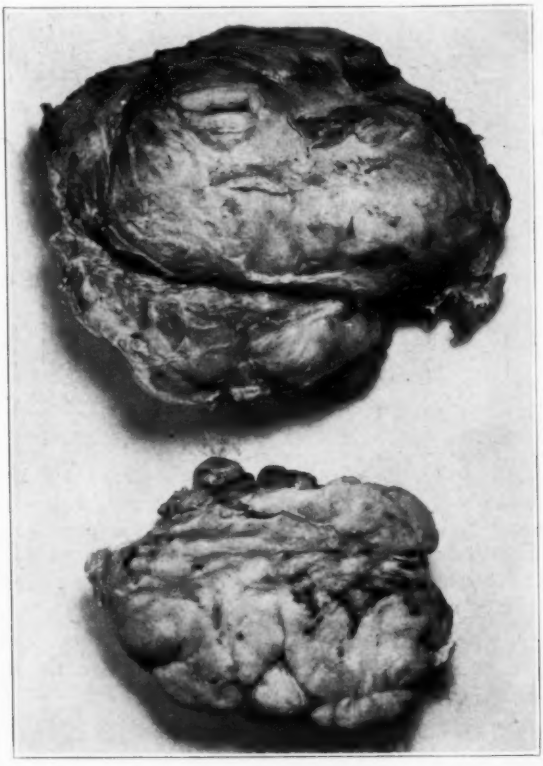

Fig. 13 (path. no. 24536).—The tumor mass is shown shelled away from the bone. The glistening fleshy surface indicates the cellular nature of the tumor which is corroborated by sections showing a tightly packed small spindle cell structure.

from the outer layers of the periosteum itself as a single pathologic entity, regardless of the fact that their source of origin in the vicinity of the bone may vary widely.

The microscopic structure of these neoplasms shows a definite cycle of histologic changes. The tumor springs from a small spindle or oat-shaped cell which transforms into a more elongated spindle shape and thence transforms into a prolonged fibroblast with an ever increasing amount of intercellular material of the eosin-staining collagenous

Fig. 14 (path. no. 23407).—Gross specimen from the case shown by roentgenogram in figure 6. The fibroid tumor which is definitely encapsulated is shown invading the bone by pressure necrosis and is clearly demarcated from the neighboring osseous substance. The microscopic structure which resembled a benign fibroma is shown in figure 22.

type. In the more rapidly growing and malignant tumors, the microscopic picture is predominantly of the small plump spindle cell type commonly known as the oat cell. The chief characteristics of this cell are the scantiness of its cytoplasm, the tightness with which it is packed and the tendency for the nucleus to assume a rounded form and to

undergo mitosis so that under high power magnification the cell has a great resemblance to a small round cell sarcoma (figs. 15, 16, 17 and 18).

Oat-shaped cells are sparse among the less malignant tumors which are composed of more truly spindle cells and fibroblasts. When these spindle cells are tightly packed but fairly elongated and arranged in bundles or fasciculae, the type of the tumor may be referred to as a spindle

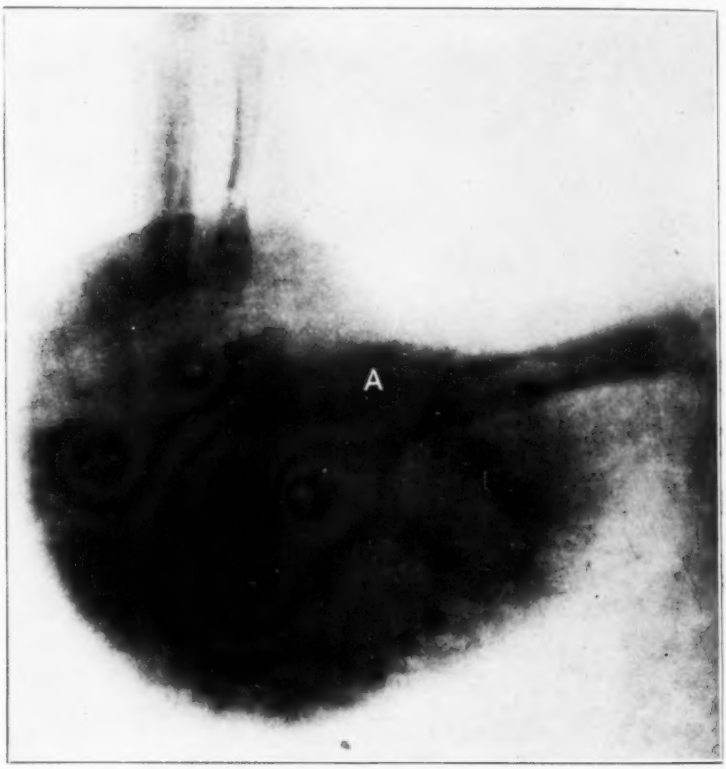

Fig. 15 (path. no. 28276).—A congenital oat cell sarcoma in the lower end of the humerus in an infant 16 days old, who was treated by amputation following an exploratory excision. The patient has remained well over nine years. The roentgenogram shows the large soft part shadow and secondary erosion of the bone resulting in a pathologic fracture.

cell sarcoma (fig. 19). When the spindle cell is replaced in many instances by the fibroblast and there is an increasing amount of intercellular substance, the tumor may be called a fibrospindle cell type (figs. 20 and 21); when the fibroblast predominates and is scattered among a large amount of intercellular collagenous material, the tumor verges on a benign fibroma and may be termed a fibrosarcoma (fig. 22).

This gradual transition from oat cells to spindle cells to fibrospindle cells and to adult fibroblasts permits a definite grading on which a prognosis and the type of treatment may be based, for this transition of cell forms represents the true histogenetic cycle of the tumor. This is evidenced by embryologic studies of the primitive connective tissue surrounding the region of the bone (fig. 23). In this primitive connective tissue the cellular elements are of the oat and spindle cell types

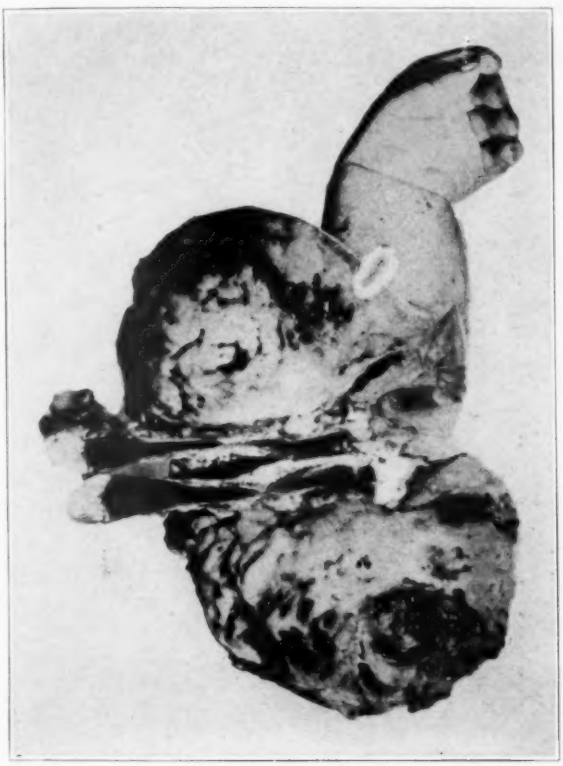

Fig. 16 (path. no. 28276).—The amputated specimen indicating the cellular and hemorrhagic character of the new growth.

with a scanty amount of intercellular substance resembling markedly the less differentiated oat and spindle cell sarcomas.

When the tumors are of the oat cell type with little or no intercellular substance, the neoplasm is exceedingly malignant and warrants the most radical treatment. These oat cell tumors can be readily distinguished from the fibrospindle cell and fibrosarcomas in which there is a greater tendency for whorl formation and a definite amount of collagenous intercellular substance, and the patho-

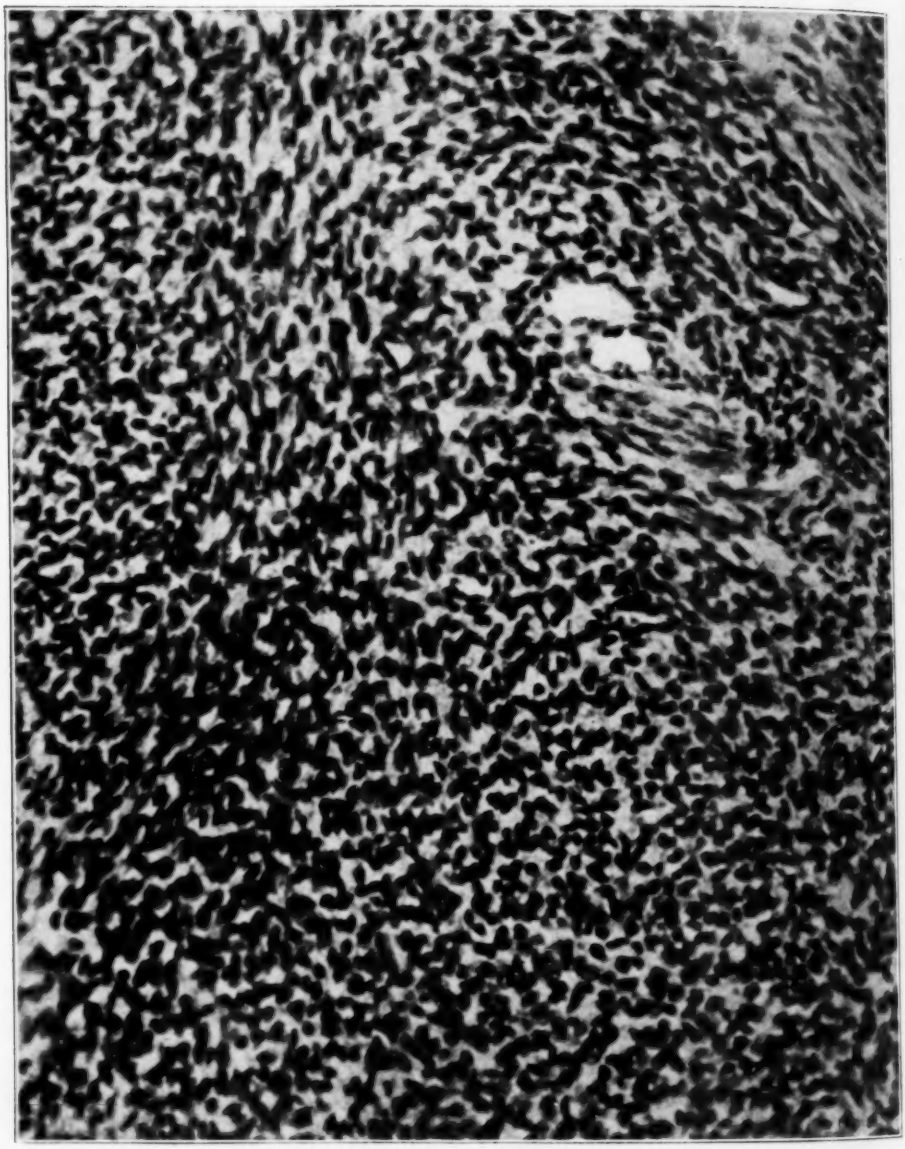

Fig. 17 (path. no. 28276).—Low power photomicrograph indicating the tendency for the small oat cell to take on a more spindle shape and arrange themselves in definite bands or trabeculae.

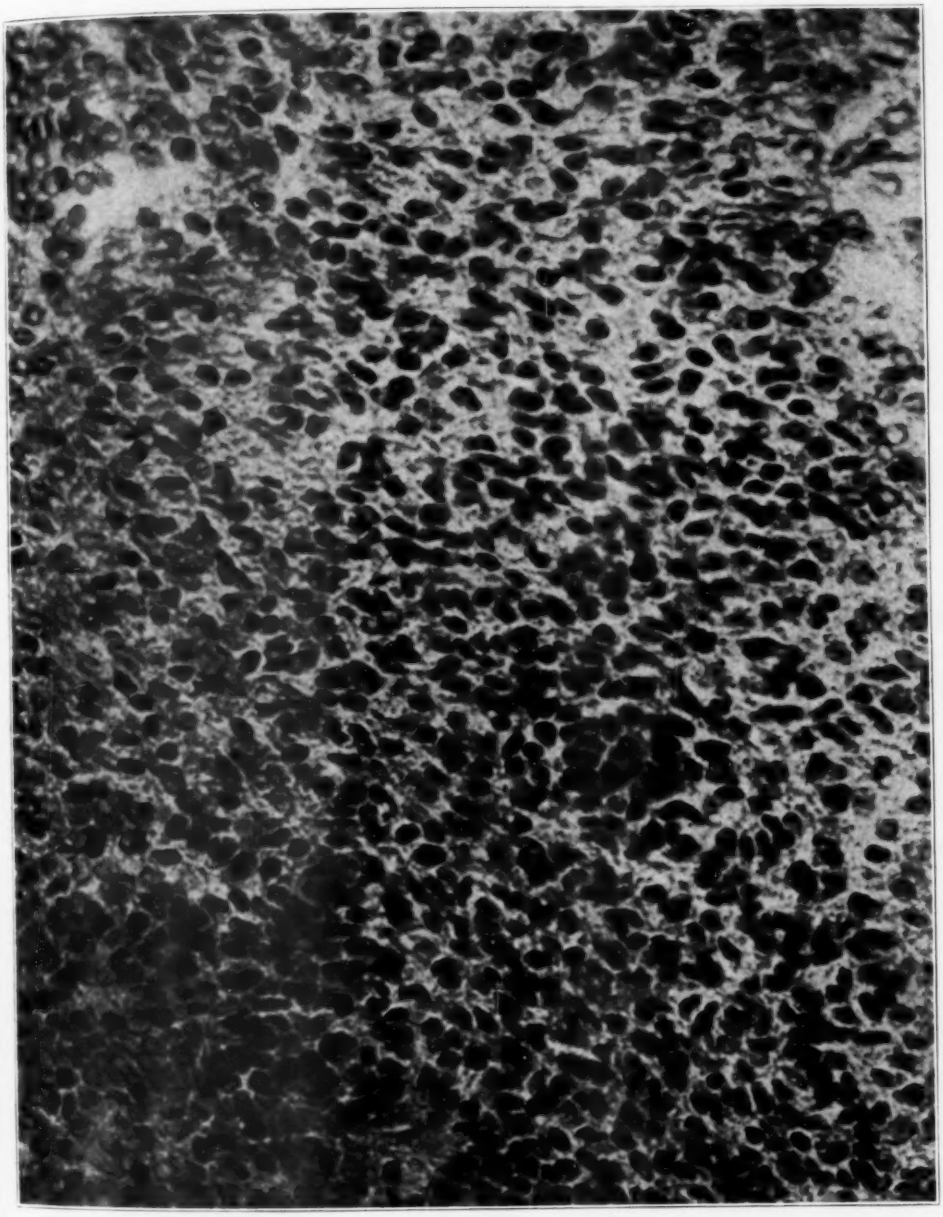

Fig. 18 (path. no. 28276).—High power photomicrograph indicating the resemblance of the tumor to small round cell sarcoma under high power.

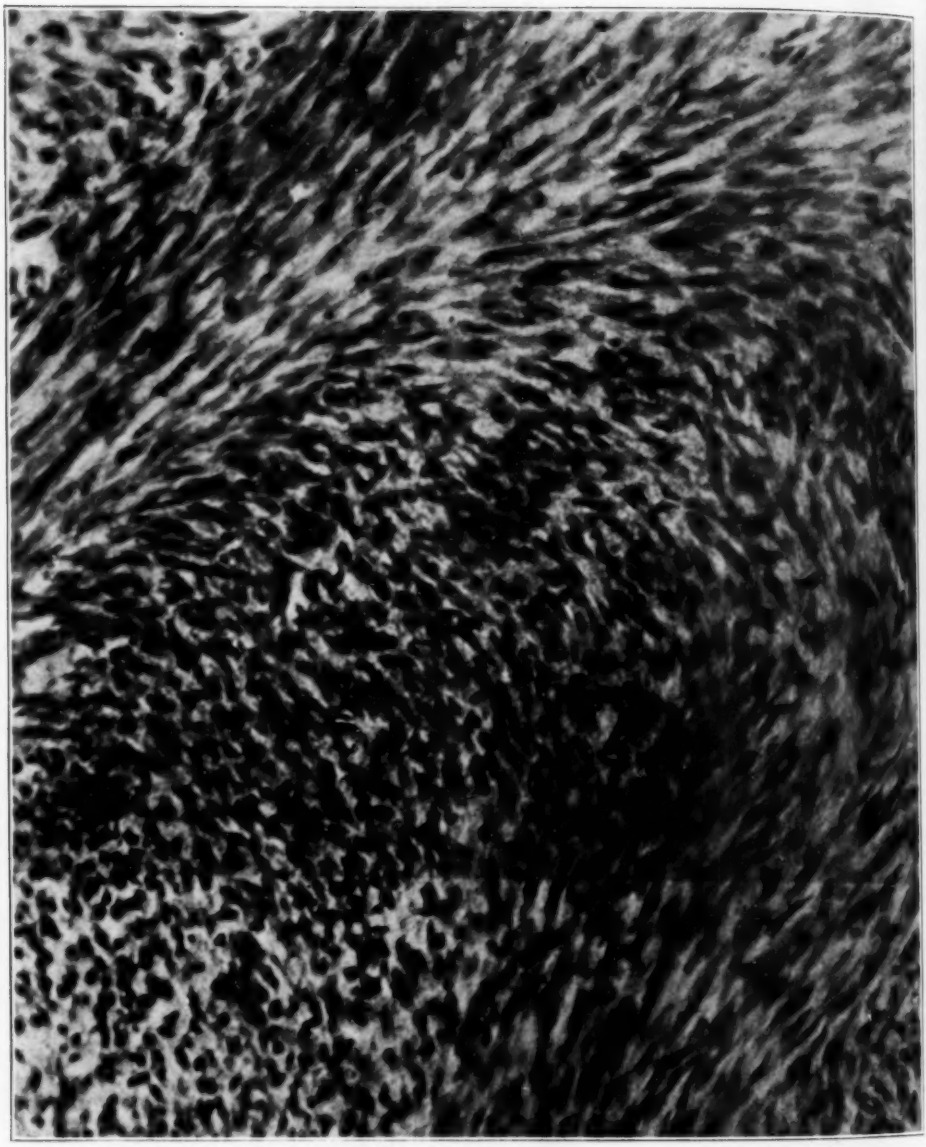

Fig. 19 (path. no. 31267).—A spindle cell sarcoma invading the skull of a white woman, aged 34, which resulted in death five years after an incomplete excision. The tumor is composed of characteristic fasiculae, and the predominant cells grade midway between the oat cell and the fibroblasts, although both of these other types are present.

Fig. 20 (path. no. 27555).—Low power photomicrograph of a fibrospindle cell sarcoma, showing the tendency for the spindle cells to assume the characteristics of fibroblasts and lay down a definite amount of intercellular collagenous material. The prognosis in this grade of fibrospindle cell sarcoma following a radical operation is extremely favorable. The tumor illustrated was from the radius of a white man, aged 49, who has remained well over seven years following amputation.

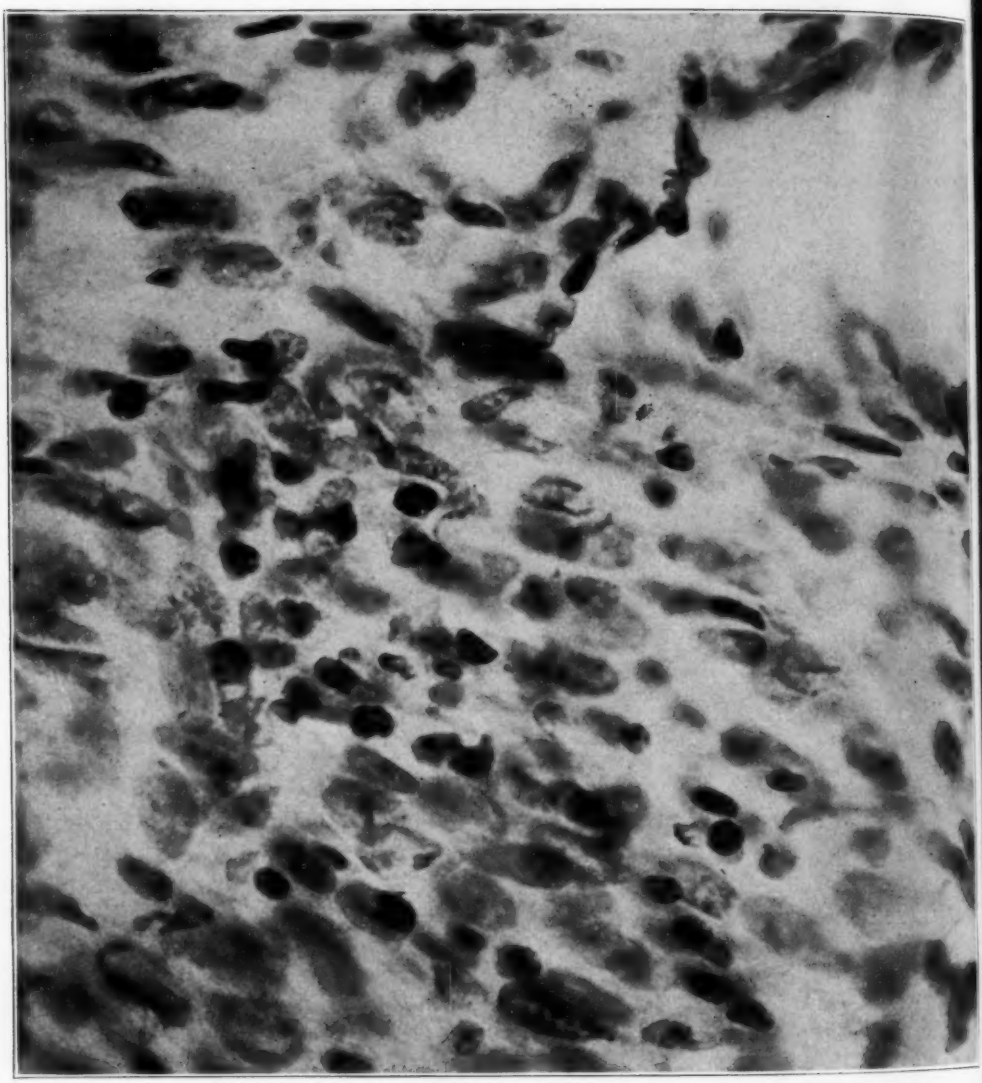

Fig. 21 (path. no. 38182).—High power photomicrograph of fibrospindle cell sarcoma, the gross specimens of which is shown in figure 10. The illustrations show the variety of cells grading from oat cells to fibroblasts included in these types of tumors. Note the tendency for the nuclei of the sarcomatous cells to assume a large vesicular form.

logic behavior and prognosis is sufficiently different to warrant setting them aside as a definite subgroup in which the grade of malignancy is extreme.

On the other hand, the more benign fibrospindle cell and fibrosarcomas in which many fibroblasts are present with an abundant

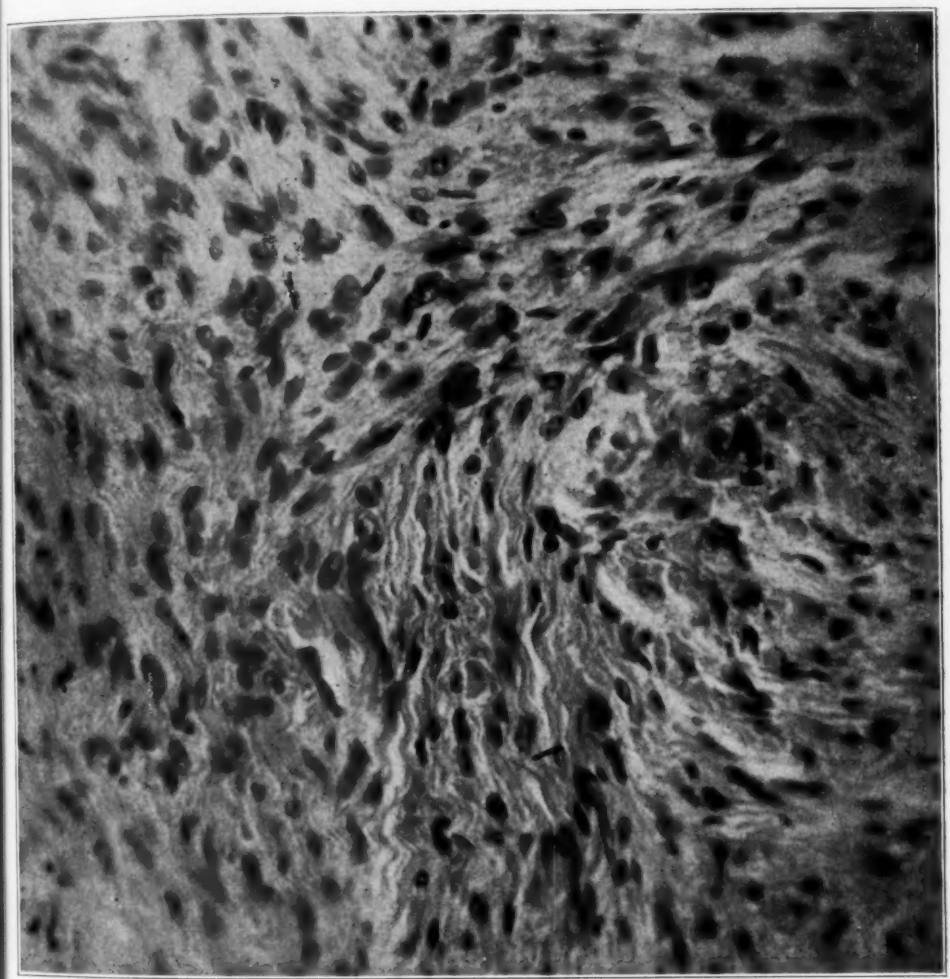

Fig. 22 (path. no. 23407).—Photomicrograph of the tumor shown in figures 6 and 13. The tumor is composed predominantly of adult fibroblasts with a conspicuous amount of collagenous intercellular substance. The nuclei are small, and the tumor is essentially a rapidly growing fibroma.

amount of intercellular substance are very slowly growing sarcomas that metastasize late despite a tendency to recur locally. They con-

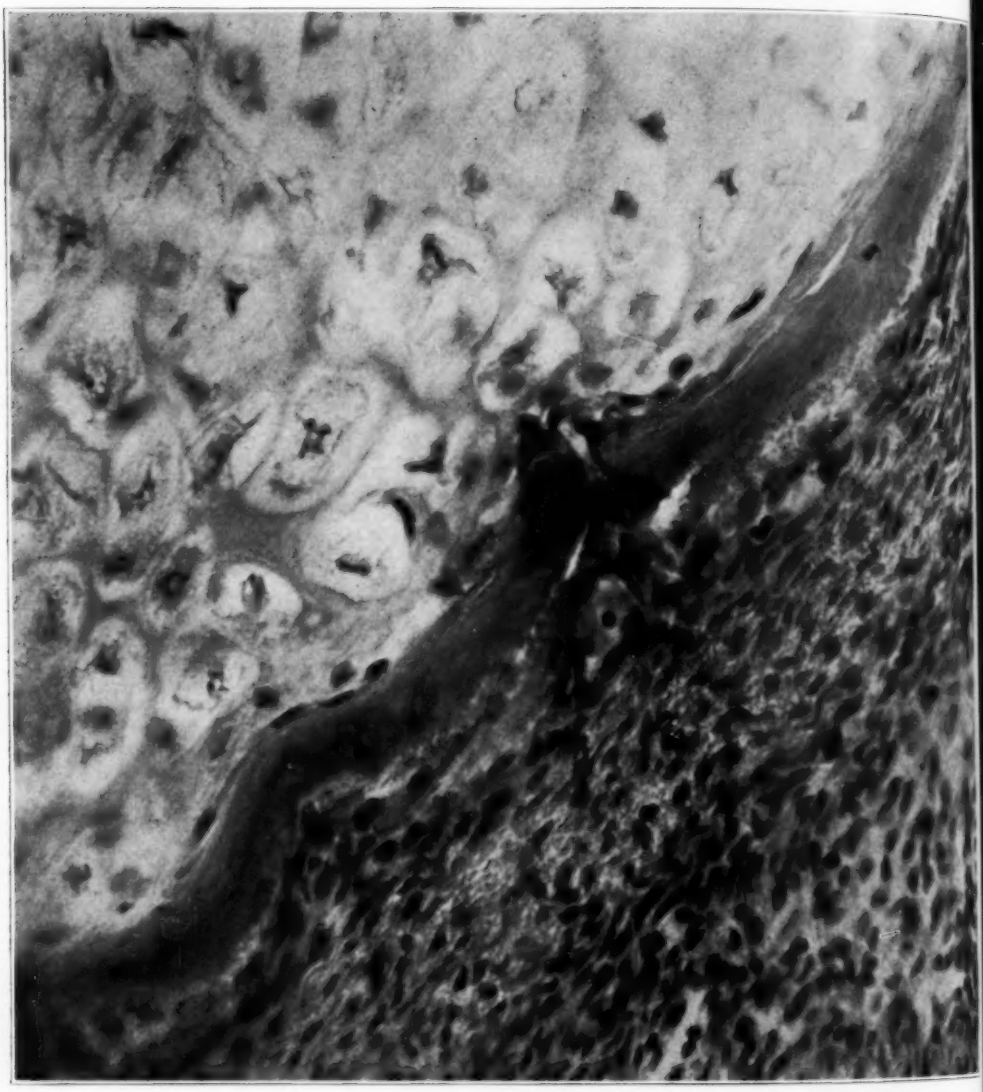

Fig. 23 (path. no. 40934).—Photomicrograph taken at the margin of a cross-section of the humerus in a human embryo of 90 mm. The humerus is composed at this stage of calcified cartilage surrounded by a small rim of osteoid substance. Outside of this osteoid cuff is seen the primitive periosteum composed of oat and spindle cells or embryonic fibroblasts. The photomicrograph supports the contention that the cycle of histogenesis in fibrosarcoma is from oat cell to fibrospindle cell to fibroblast.

stitute another subgroup in which the grade of malignancy is definitely low.

In between the oat cell type and the more highly differentiated fibrospindle cell forms is the spindle cell sarcoma which merges on the one hand with the oat cell type and on the other with the fibrospindle cell series. If the cellularity in this type of tumor is marked, and if there is any resemblance to the oat cell type, it is best to be on the safe side and treat it radically in the same manner.

These various forms or grades of fibrosarcoma are to be distinguished from osteogenic sarcoma of the bone by the absence of cartilage or bone formation. Unlike the osteolytic variety of osteogenic sarcoma in which both cartilage and bone formation may be absent, the nuclei of these tumors show little or no tendency toward bizarre malignant forms, and tumor giant cells are absent (fig. 24). The presence of small giant cells of the epulis type may occur, but these are rare and are usually associated with spicules of bone undergoing necrosis.

These tumors of the fibrosarcoma group must also be distinguished microscopically from sarcoma of neurogenic origin which may secondarily invade the bone and which has quite distinct growth properties. The myxomatous substance, the elongated waving nucleus with the tendency to fibrillae formation and the enlarged tumor giant cell which are all typical of neurogenic sarcoma (fig. 31) are not characteristic of these neoplasms.

Prognosis and Treatment.—The prognosis and treatment of these tumors depends primarily on an accurate microscopic analysis, and secondarily on the degree of bone invasion and on the type of involvement of important vessels or nerves. From the microscopic standpoint, it is essential to rule out the more malignant neurogenic sarcomas and the more highly malignant osteogenic sarcomas. This is not always an easy matter, but a careful perusal of the photomicrographs included here together with the diagnostic points just mentioned will permit a fair degree of accuracy in this regard.

If the tumor is microscopically of the fibrospindle cell series, it is necessary to grade its degree of malignancy by determining whether it is of, or closely related to, the oat cell type or whether it resembles, or belongs to, the more highly differentiated fibrosarcoma group. In the present series of thirty-one cases in the fibrospindle cell series little difficulty was experienced in dividing these tumors into the undifferentiated and differentiated form (tables 1 and 2). This was done on a purely microscopic basis without knowledge or reference to the clinical results. After this microscopic grading had been carried out, the clinical features and the results of treatment were tabulated for the two separate groups, the more differentiated spindle, fibrospindle and

Fig. 24 (path. no. 27852).—High power photomicrograph of an osteolytic variety of osteogenic sarcoma showing the bizarre nuclear forms characteristic of this very malignant tumor in contradistinction to the more benign fibrospindle cell sarcoma.

fibrosarcoma tumors being placed in one group and the more malignant and undifferentiated oat cell type in the other.

Twenty-two cases were placed in the differentiated fibrospindle cell group. The ages of the patients ranged from 12 to 58 and the duration of the tumor from one to forty-eight months. None of these patients died within a period of five years after treatment, if exception is made of one patient who succumbed to tuberculous pneumonia and another on whom curettement followed by radium implantation was done. Even when adequate treatment was not given, as in case 31267 (fig. 19) in which the neoplasm invaded the skull, the duration of life reached five years. In all cases of primary amputation in which adequate follow-ups are available, the patients were cured and are living from six to twelve years after operation. When local operation was done the tumor invariably recurred, although in most instances life was prolonged beyond five years by an ultimate amputation or by further excision accompanied by deep roentgen or radium therapy. Repeated local operations, however, have never proved sufficient to cure a case, although a woman of 33 with a tumor in the region of the lower end of the femur lived for nine years before ultimately succumbing to pulmonary metastases.

The value of deep roentgen and radium therapy is difficult to establish in these cases. The tumor is not particularly radiosensitive, and after a local operation followed by roentgen therapy and radium the tumor has usually recurred. The outstanding conclusion that can be drawn is that in face of marked bone involvement a local operation is insufficient in these tumors of the fibrospindle cell group, and even local operation plus roentgen and radium therapy is usually not sufficient to prevent a recurrence. The tumor, however, is slow to metastasize and may be held in check from five to ten years by repeated local operation accompanied by roentgen or radium therapy.

Whether to combat the tumor by repeated treatment or insure its eradication by primary amputation depends on its location and the degree of bone involvement. In a vital location such as the skull, repeated excision accompanied by roentgen or radium therapy is the only procedure possible. In the extremities, if bone involvement is not marked and the cortex is still intact and if the important vessels and nerves are not included in the tumor mass, local excision may be tried if the tumor is encapsulated, and an attempt made to save the limb. The microscopic pathologic process, however, must be checked at operation to rule out the oat cell type of fibrospindle cell sarcoma and to rule out the mixed spindle and large cell sarcoma of neurogenic origin. If the local operation is done, it should be followed by deep roentgen or radium therapy. When the tumor recurs, the limb should be promptly amputated.

When bone involvement is marked and important vessels and nerves are included in the tumor mass, the function of the limb cannot be saved, and the difficulty in eradicating the tumor with the consequent danger of recurrence justifies an amputation.

When the tumor is of the undifferentiated oat cell type, neither local excision nor roentgen or radium therapy offer anything in the way of a permanent cure, and if the location of the tumor permits, primary amputation should be done. These conclusions are supported by the data shown in table 2. It will be seen that of the nine cases tabulated, permanent cure was obtained in only one (a tumor in the lower end of the humerus present in an infant at birth), and in this instance primary amputation was performed. In the case in which radium therapy was attempted it was of no avail, and even primary amputation did not suffice to establish a cure in most instances.

NEUROGENIC TUMORS INVOLVING BONE

While the connective tissue tumors of the fibrospindle cell group that invade bone may arise at variable sites in the investing fascia about such structures as bone and muscle, vessels, etc., it is possible that a group of tumors of quite different and more specific cellular composition may arise among these same structures overlying the bone and produce similar osseous involvement. Such tumors have a cellular composition that identifies them with the structure from which they arise and vary in their histology according to the tissue of origin. Among this group of tumors must be enumerated, neurogenic sarcoma, angiomas, myosarcoma and lipomas.

In the present series of cases there were fourteen tumors involving bone that could be specifically related to nerves in the vicinity. These new growths showed by the presence of wavy nuclei, fibrillae, myxomatous substance and tumor giant cells an origin from neural elements. They could also be related by microscopic appearance, clinical and pathologic behavior, to a far larger group of subcutaneous and soft part tumors of known neurogenic origin studied in this laboratory (Lewis and Hart [2]).

Clinically and in the roentgenogram, these neurogenic tumors (table 3) bear a close resemblance to the lesions of the fibrospindle cell series just discussed. Pathologically, also, the similarity is marked between the two groups. Like the fibrosarcomas, the neural tumors may have a marked fibrillar structure and show under the microscope many spindle cells (fig. 31). Like these fibrous growths that show a continual gradation from the benign fibroma to the most malignant spindle cell forms,

2. Lewis, Dean; and Hart, Deryl: Tumors of Peripheral Nerves, Ann. Surg. **92**:961, 1930.

TABLE 2.—*Undifferentiated Forms of Fibrospindle Cell Sarcoma*

Path. No.	Race	Sex*	Age	Location	Duration, Mo.	Symptoms	Roentgenologic Picture	Treatment	Microscopic Picture	Result
38672	W	♂	25	Femur, lower	...	Pain, tumor	Osteoporosis, periosteal shadow	Explored, amputated December, 1922	Oat cell sarcoma	Living 3½ yr.
35908	W	♂	30	Tibia, upper	72	Trauma, pain, swelling, latter two 6 wks.	Soft part shadow, considerable secondary bone destruction	Curettement, June, 1923; amputation, July 13, 1923	Oat cell sarcoma	Dead 5 mo. following amputation
30748	W	♀	30	Femur, upper	...	Pain, tumor	Soft part shadow, bone destruction	Excision, June, 1922	Oat and spindle cell sarcoma	Dead of tumor, no date
29691	W	♀	40	Tibia, left lower	96	Pain, tumor, trauma	Soft part shadow, slight secondary bone destruction	Exploration with cautery, amputation	Oat cell sarcoma	Dead within 16 mo. following amputation
28276	W	♀	½	Humerus, lower	6	Tumor at birth	Large soft part shadow, advanced secondary bone destruction	Excision, amputation, June 8, 1920	Oat cell sarcoma	Well 9 yr., 11 mo. following amputation
26404	W	♂	..	Sacrum	...	Trauma, pain and tumor	.....	Excision, radium	Oat cell sarcoma	Dead 6 mo. following injury
24520	W	♂	..	Pelvis	...	Tumor	.....	Resection of hip joint May 10, 1919	Oat cell sarcoma	Dead 2 yr. later
13350	W	♀	69	Humerus, lower	108	Fracture, subsequent swelling, pain, limitation of motion	.....	Amputation, Oct. 22, 1912	Oat cell sarcoma	Dead 2 yr., 1 mo. later
7583	W	♂	40	Femur, lower	12	Trauma, pain, tumor	.....	Amputation, Sept. 29, 1906	Oat cell sarcoma	Dead 6 mo. later

* ♀ indicates female, ♂ male.

there is also a gradual transition among the neural tumors from the benign neurinomas to the most malignant forms of neurogenic sarcoma.

Unfortunately for the treatment of sarcoma in general, and particularly for the forms of sarcoma most frequently localized in the extremities, the pathologic distinction between tumors of the fibrospindle cell series and tumors of the neurogenic series is not frequently made. Nor, in most instances, is the pathologist familiar with the variations in the histologic picture that accompany the gradations from the more benign fibromas to the more malignant oat cell sarcomas in contrast to the transitions that accompany the gradations between the more benign neurinomas and the more malignant neurogenic sarcomas. As a result, much confusion has arisen in the literature in regard to the diagnosis and prognosis of these growths and in regard to the proper forms of treatment.

In those neurogenic tumors that invade the bone, the more malignant and cellular forms predominate, and in no instance of this series was there any difficulty in setting the tumor apart as a sarcoma as opposed to a benign neurinoma. This cellular sarcoma structure is in keeping with the invasive character of the growth which has forced its way into the osseous substance. While thus easily distinguished from the benign neurinomas, careful microscopic study was necessary to delineate these growths from fibrospindle cell sarcoma. However, that the microscopic distinction was accurately made is borne out by the clinical features and results of treatment. The clinical follow-ups show that once a neurogenic sarcoma has invaded the bone the chances for cure, no matter how radical the mode of treatment, are practically nil.

Clinical Features.—While the most important points of distinction are not clinical or roentgenologic but relate to the pathologic process and to the response of the neurogenic tumors to treatment, these neoplasms nevertheless present definite clinical peculiarities. The age of the patient is usually well over 30 (from 32 to 75), and the duration of clinical symptoms averages over one year. In only one case of neurogenic sarcoma involving the bone in this series was a child affected. This was in a white boy of 7, who had a tumor in the soft parts of the buttocks (fig. 25), and in this instance, the osseous involvement differed from that in the other cases in that the extension to the bone which involved the skull and the vertebra was due to metastases to these regions.

The bone involvement as shown in the roentgenogram (figs. 26, 27, and 28) is more pronounced in those instances due to neurogenic sarcoma than in the cases caused by fibrospindle cell sarcoma. Pathologic fracture may occur (fig. 26), and the lesion may resemble metastatic

TABLE 3.—*Neurogenic Sarcoma Involving Bone*

Path. No.	Race	Sex*	Age	Location	Duration, Mo.	Symptoms	Roentgenologic Picture	Treatment	Microscopic Picture	Result
43742	W	♀	37	Tibia, upper	12	Pain, swelling	Soft part shadow, roughening of bone	Roentgen therapy, complete excision, December, 1930	Neurogenic	.....
43482	W	♂	38	Tibia, upper	72	Pain, swelling	Soft part shadow, large area of bone destruction	Amputation, August, 1930	Neurogenic	.....
38722	W	♂	73	Fibula, upper	24	Pain, tumor	.....	Curettement, December, 1926; radium, postoperative x-ray	Neurogenic	.....
38304	W	♀	37	Fibula	12	Pain along distribution of nerve, swelling	Soft part tumor, bone erosion	Refused treatment	.....	.....
36721	W	♂	75	Femur, lower	..	Pain, tumor	.....	Amputation, Jan. 29, 1925	Neurogenic	Dead 7 mo. later
35248	W	♀	16	Tibia, upper	..	.....	Soft part shadow, secondary bone destruction	Amputation, Oct. 21, 1924; preoperative x-ray, Feb. 23, 1924	Neurogenic	Well 5 yr. and 7 mo.
34628	W	♂	44	Ischium and groin	2	Pain, swelling	Bone erosion	Radiation (radium); excision, May, 1921	Neurogenic	Dead 11 mo. later
33928	W	♂	46	Femur, lower	4	Pain, pathologic fracture	Soft part shadow, extensive bone destruction	Exploration; Sept. 11, 1923; x-ray, amputation, Sept. 23, 1923	Neurogenic	Dead 14 mo. later
30855	W	♂	7	Buttocks, skull	1	Pain, swelling	Bone destruction in skull	Exploration, Dec. 12, 1921; radium, January, 1922	Neurogenic	Dead 2 yr. later; metastasis plural; extension of tumor through dura to brain; skull and thoracic vertebrae involved with tumor
27822	...	..	..	.....	10	.....	.....	.....	.....	Well over 1 yr.
26593	W	♂	77	Femur, lower	10	Pain, tumors	Soft part shadow, advanced secondary bone destruction	.....	Neurogenic	Dead 2 yr. later
26178	W	♂	32	Femur, lower	12	Pain, tumor four months	.....	Resection, May 29, 1920; bone graft	Neurogenic	Dead 7½ mo. following operation
25888	W	♂	37	Femur, lower	5	Tumor, pain, pulsation	Soft part shadow, secondary bone destruction	Irradiation, March, 1920	Neurogenic	Dead 2 mo. later
17671	W	♀	65	Radius, upper	6	Pain, tumor	Soft part shadow, complete secondary destruction of upper end of radius	Amputation, June 12, 1915	Neurogenic	Dead 6 mo. following operation

* ♀ indicates female, ♂ male.

carcinoma or osteolytic sarcoma of central origin. In other respects the roentgenogram bears a remarkable resemblance to those seen in fibrosarcoma of bone. The unique changes in the length and structure of the bone which may be brought about by the benign types of von Recklinghausen's neurofibromatosis are not included in this study.

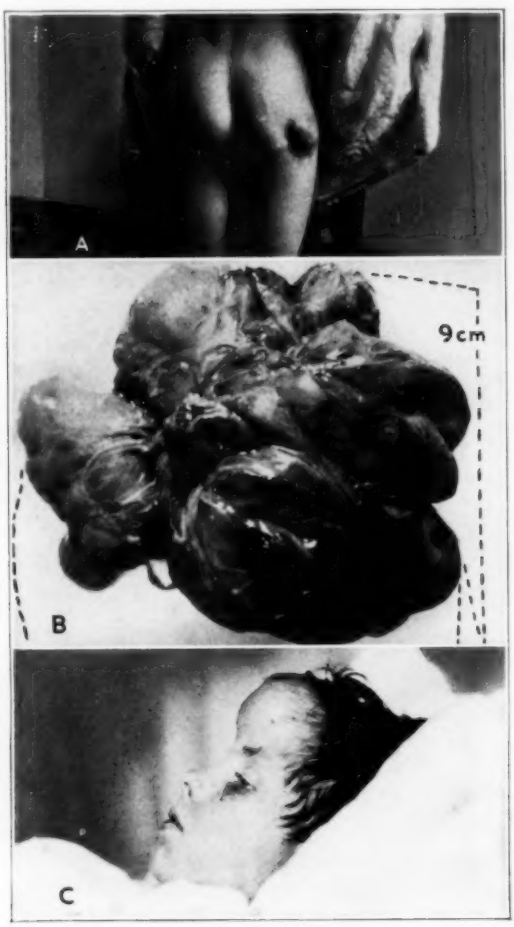

Fig. 25 (path. no. 30855).—A case of neurogenic sarcoma arising in the soft part of the buttocks of a white boy, aged 7, and invading the bone. *A* shows the original tumor which was removed by excision; *B*, the gross specimen after removal. Note the lobulated character of the growth and its gelatinous mucoid appearance. *C* shows the metastasis to the frontal bone, which invaded the dura and penetrated into the brain substance. The vertebrae were also involved by metastases. The patient died two years after the initial operation despite radium treatments.

Symptoms referable to nerve involvement, such as tingling or pain along the distribution of the nerve trunk, were not marked in this group, and once the tumor developed to an appreciable size the disturbances referable to the bone involvement dominated the clinical picture.

Pathology.—Grossly, these neurogenic tumors are less firm and more fleshy than fibrospindle cell sarcoma. They have either a soft and beefy red appearance or are composed of a gray translucent jelly-like myxom-

Fig. 26 (path. no. 33928).—Roentgenogram of neurogenic sarcoma occurring in a white man, aged 26, who died fourteen months following amputation. The lateral view shows well the soft part tumor invading the popliteal space. Opposite this point the entire osseous substance of the femur had been destroyed and a pathologic fracture has occurred.

atous substance. The fleshy tumor, besides finding its way into the bone, is locally disseminated along the neighboring nerve trunk, and this structure shows a decided tendency to be diffusely involved by multiple discrete or lobulated tumors of this character (fig. 20 *B*). When the marrow cavity of the bone is invaded, the white translucent areas of tumor infiltration are accompanied by neighboring regions in which

hemorrhagic and honey-combed cavities are opened up in the cancellous bone (fig. 30). The periosteum is raised by the tumor growth, and the joint cavity in the vicinity may be involved (fig. 29), a complication rare in osteogenic sarcoma but occurring in fibrosarcoma affecting bones.

Under the microscope, strands of tightly packed elongated spindle cells are very common and give these tumors a superficial resemblance to the fibrospindle cell sarcoma (fig. 31). There is, however, a faintly staining myxomatous substance that is present in fairly conspicuous areas

Fig. 27 (path. no. 26593).—Roentgenogram showing a neurogenic sarcoma which is invading the femur from without. There is a soft part shadow just above the lateral femoral condyle, and opposite this point, the cortical and cancellous bone is being destroyed by direct invasion. The patient died with pulmonary metastases, two years after amputation. For microscopic structure see figure 32.

interspersed among the spindle cell bundles. Within these myxomatous areas are found degenerating cells with small nuclei and a large faintly staining amount of rounded cytoplasm (fig. 33). The elongated spindle cell areas also present definite peculiarities. The nuclei are generally longer and more deeply staining than those found in fibrospindle cell

sarcoma and are more often rippled or waved (fig. 32). The appearance of large tumor giant cells in the section among these spindle cell areas and the tendency for the cells to line up in parallel rows are important diagnostic points, the one indicating a high degree of malignancy and the other recalling the fibrillated structure of peripheral nerves (figs. 34 and 35).

Fig. 28 (path. no. 43482).—Roentgenogram of a neurogenic sarcoma invading the outer condyle of the upper end of the tibia. Note the opaque large soft part shadow. This tumor invaded the knee joint (fig. 29).

Like fibrospindle cell sarcoma, these neurogenic tumors may be definitely graded with the microscope. Frequent myxomatous areas about which clumps of elongated nuclei in cells of the neurilemma type are found in a palisade arrangement are more typical of a benign neurinoma and are more prominent in the neurosarcomas with a slower rate of growth. So are the so-called reticular areas in which cells with small nuclei are loosely scattered (figs. 36, 37 and 38). As the tumor gives

evidence of a high degree of malignancy, large pleomorphic nuclei become scattered through the tissue and the spindle shaped cells become more tightly packed. In the highly malignant cases, tightly packed spindle cells with sharply pointed nuclei crowd out the myxomatous areas, and the tumor giant cells take on a bizarre appearance.

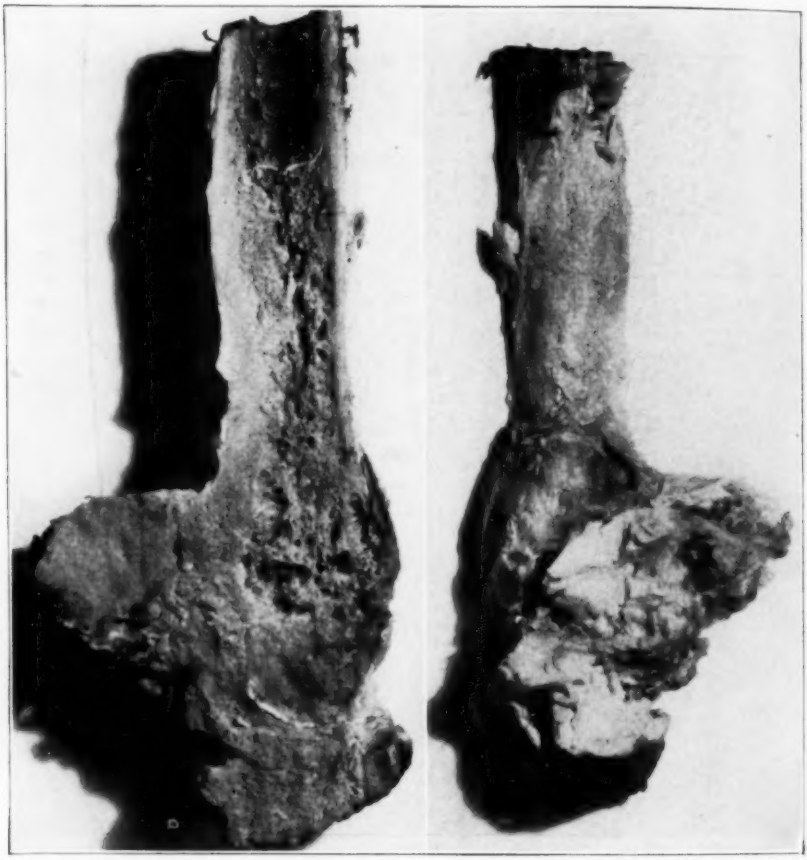

Fig. 29 (path. no. 43482).—Gross specimen of the case shown in figure 28. The specimen includes the tumor mass in the knee joint which is shown attached to and invading the lower end of the femur. The original tumor arose opposite the head of the tibia (for microscopic structure see fig. 35).

Prognosis and Treatment.—The prognosis for life in cases of neurogenic sarcoma, even after a primary amputation, is not good. These neoplasms, arising from the deep lying nerves and invading the bone, recur promptly after local operation and are not radiosensitive. Once osseous invasion has taken place, primary amputation following biopsy is the treatment of choice. There is only one cure extending over five

years in this series and this was in a young patient with a tumor invading the upper end of the tibia who was treated by amputation following a preoperative course of deep roentgen therapy. Microscopically, also, this tumor was an exception, being largely neurinomatous (fig. 36). The other eight patients who were satisfactorily traced by the follow-ups died within two years of the date of treatment, despite the fact that amputation or radical resection was done in six instances. Irradiation

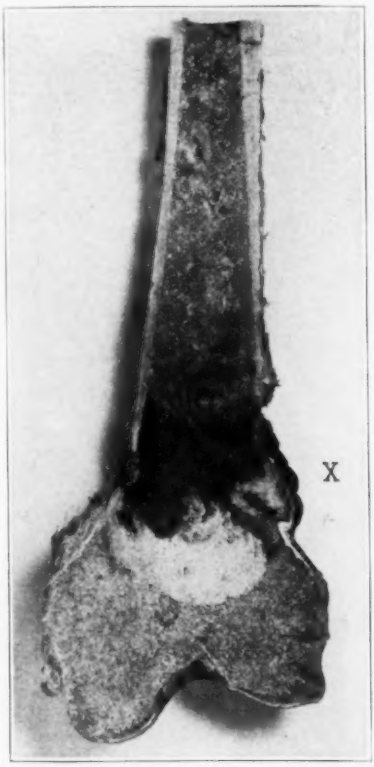

Fig. 30 (path. no. 26593).—Gross specimen of the case shown in figure 27. The tumor has gained entrance into the marrow cavity through the eroded cortex at the site marked *X*. A portion of the tumor infiltrating toward the epiphysis is of a white myxomatous character, while above hemorrhagic spaces have been opened up in cancellous bone.

with x-rays or radium was used in three of these fatal cases. When local operation was performed, the tumor recurred promptly, and in one instance (fig. 39) in which operation was not performed because of suspected pulmonary involvement by tumor metastases, death followed within two months, although the patient had symptoms referable to the bone involved for only five months previous to examination.

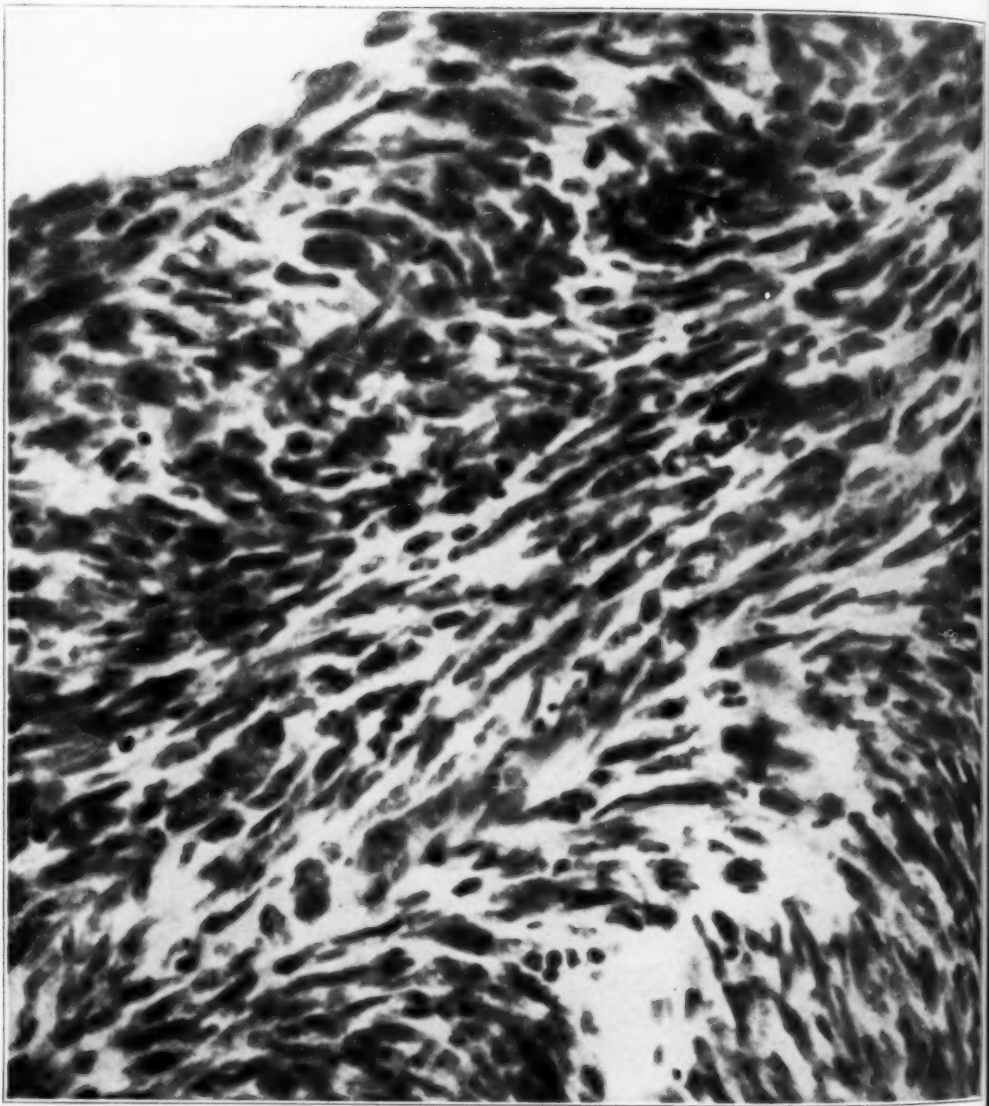

Fig. 31 (path. no. 26593).—Photomicrograph of section taken from a specimen shown in figure 30. This neurogenic tumor, although having a superficial resemblance to fibrosarcoma, shows myxomatous areas (lower right hand corner), a tendency for the cells to line up in straight rows and tumor giant cells.

Fig. 32 (path. no. 26593).—Photomicrograph of another section from the specimen shown in figure). In this area, in addition to the tumor giant cells, the nuclei have a wavy or rippled appearance, haracteristic of neurogenic sarcoma. There is a definite formation of fibrillae and a very scanty mount of intercellular substance. Again the cells are lining up in definite rows.

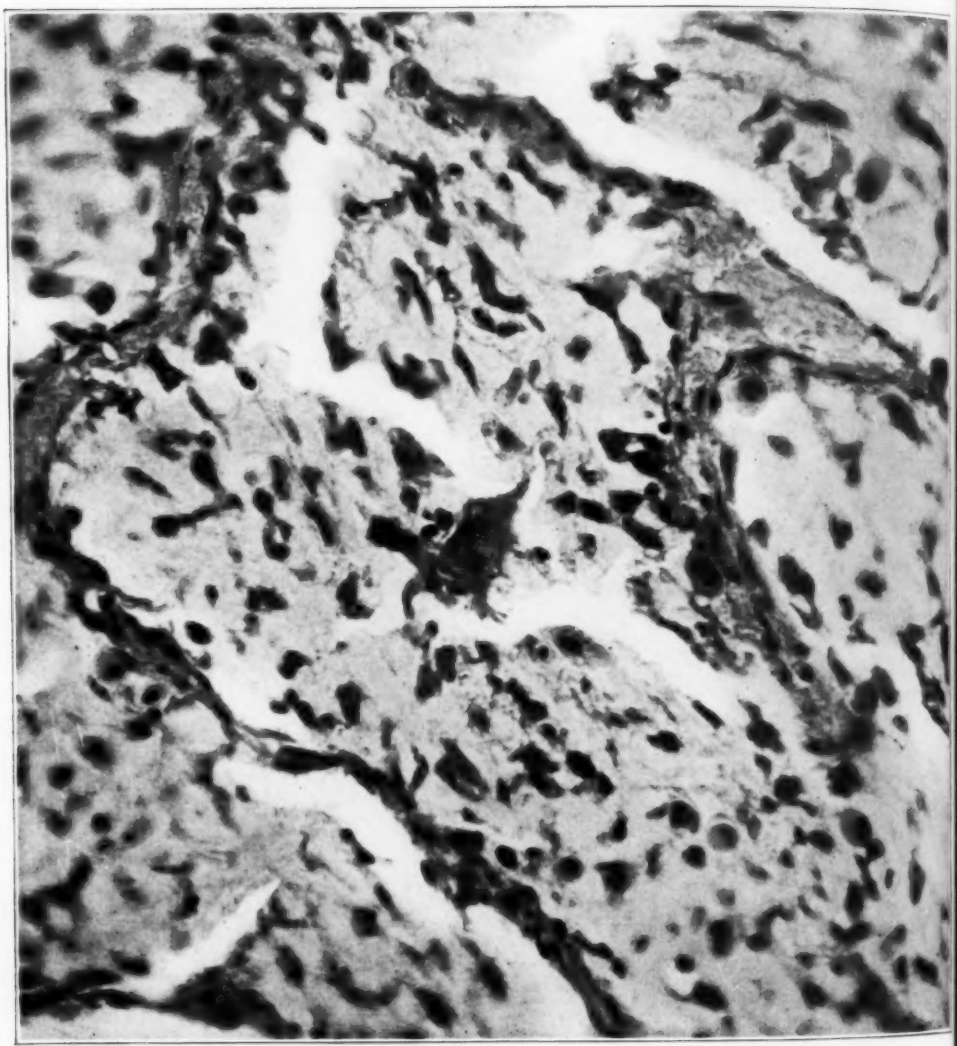

Fig. 33 (path. no. 36721).—Photomicrograph showing myxomatous areas of a neurogenic sarcoma. The patient was a white man, aged 75. The tumor occupied the popliteal space. It invaded the muscles and fascia, destroyed the femoral shaft, involved the external condyle and was beginning to invade the upper end of the tibia. The cavities in the bone were filled with a gray translucent material, typical of neurogenic sarcoma. The patient died seven months after amputation.

While the present series is too small to permit unequivocal conclusions in regard to therapy, the results observed are in accord with a far larger series of cases of neurogenic sarcoma of the same pathologic type, which occurred in the soft parts without osseous involvement. From

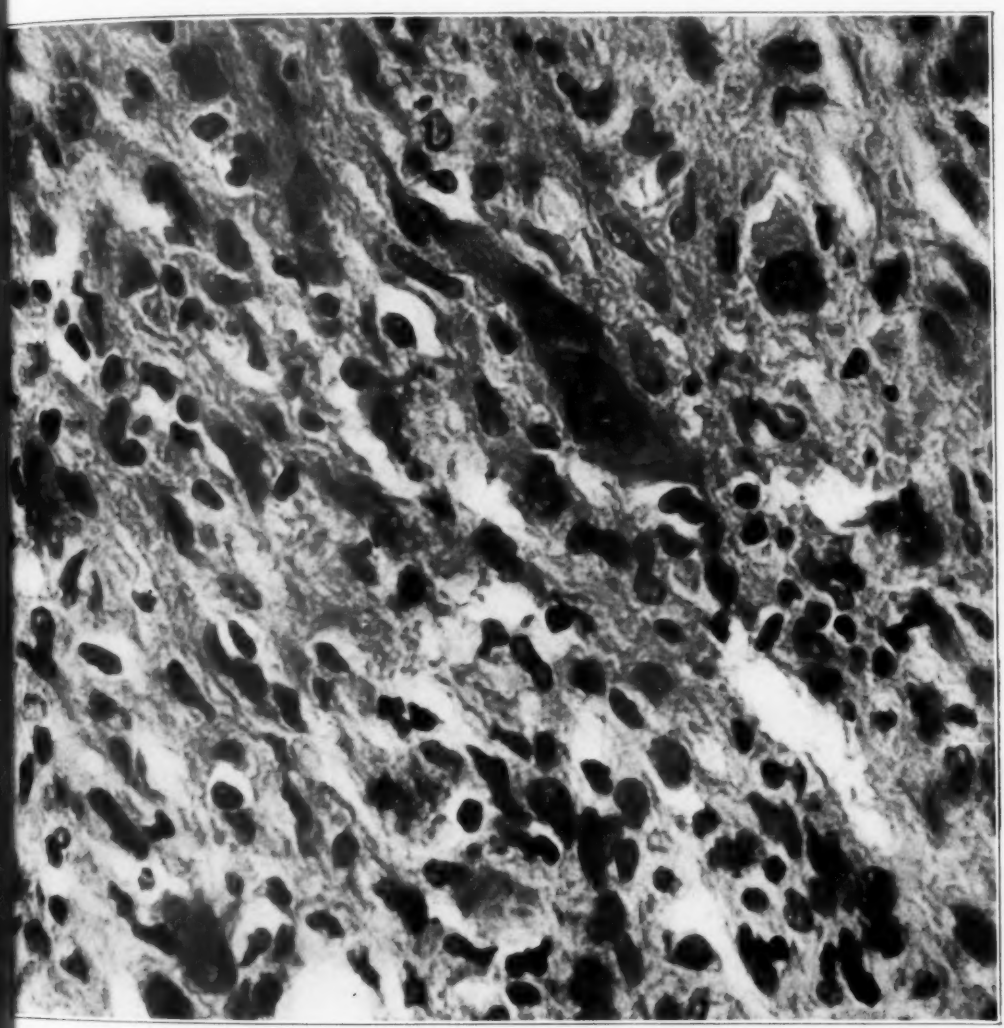

Fig. 34 (path. no. 36721).—A fibrous area in the tumor shown in figure 33. In addition to the cells resembling fibroblasts, tumor giant cells are present. A tendency to form fibrillae and areas of reticulation (typical of neurogenic sarcoma) are seen.

these combined studies it can be said that the cellular forms of neurogenic sarcoma are rarely cured, either by extensive local operation or by

irradiation with deep roentgen rays or radium. The best results are achieved by early primary amputation, and even with this radical form of treatment permanent cures are not numerous.

This gloomy outlook in neurogenic sarcoma involving bone is in marked contrast to the results obtained in the group of fibrosarcomas described in the first part of this paper. In this less malignant group it will be recalled that cures extending beyond five years were the rule,

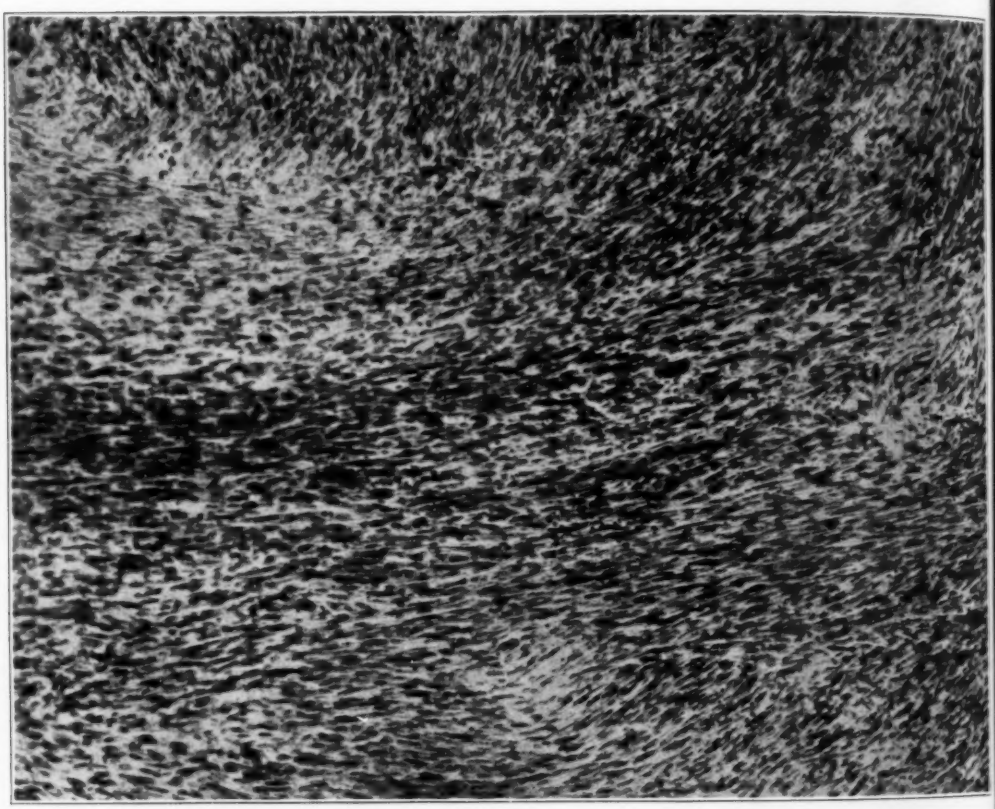

Fig. 35 (path. no. 43482).—Photomicrograph of the tumor shown in figures 28 and 29. The photograph shows well the presence of myxomatous areas, the alinement of the cells in definite rows and the large anaplastic nuclei, typical of neurogenic sarcoma.

even after the late amputation following initial recurrence. The contrast in the results between these two otherwise similar groups of tumors emphasizes the importance of distinguishing between them. Heretofore all of these neoplasms invading the bone from without by direct extension have either been loosely classed as parosteal fibrosarcoma or confused with primary sarcoma of the bone. In fact, most of the cases

Fig. 36 (path. no. 35248).—Transitions in neurogenic sarcoma from the more benign neurinomatous type of malignancy to the more malignant forms. The early malignant change in the neurinoma is shown. Myxomatous tissue predominates, and the nuclei have a palisade arrangement.

reported here were originally diagnosed from the clinical and pathologic standpoint as primary sarcoma of the bone. It is important to bear in mind that these tumors of nonosseous origin that invade bone by direct

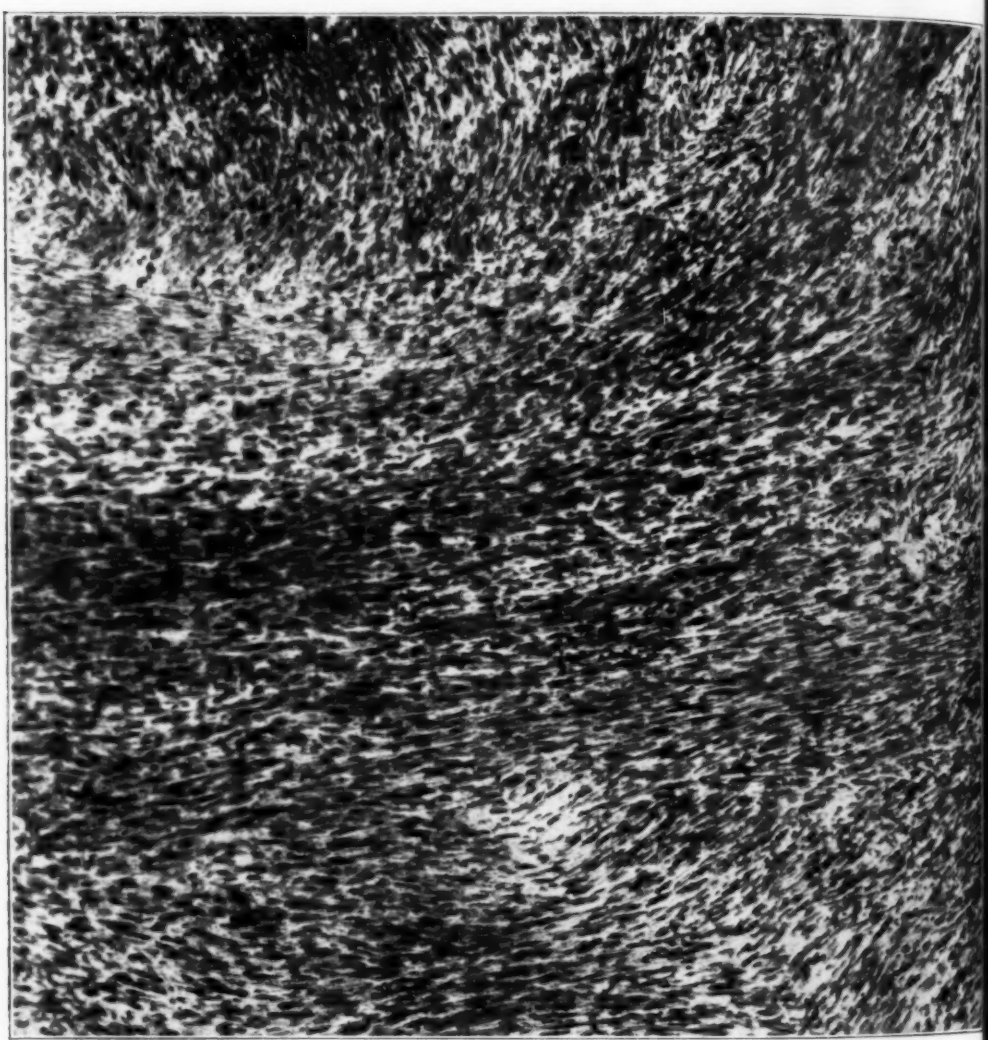

Fig. 37 (path. no. 43482).—Photomicrograph of a more malignant neurogenic sarcoma showing crowding of the nuclei, anaplastic large nuclear forms, and scarcity of intercellular substance.

extension have a variable pathologic process. When in the fibrosarcoma group and not of the oat cell type, the outlook for a permanent cure with proper treatment is exceedingly favorable if not certain (88

per cent of the patients are living after five years). When the neoplasm is of the neurogenic sarcoma type and involves the bone, the outlook is practically hopeless if the lesion is of a very cellular type, and even if the

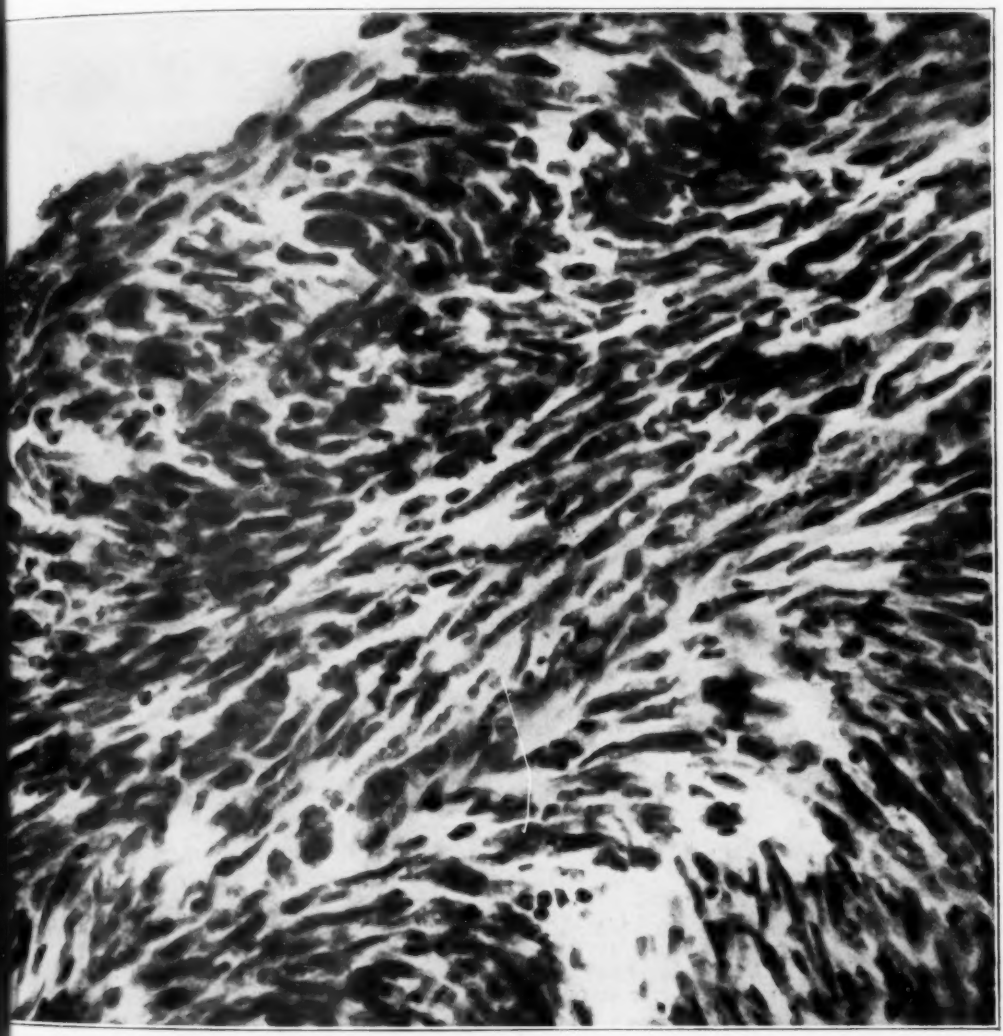

Fig. 38 (path. no. 26593).—Very malignant neurogenic sarcoma showing a microscopic picture predominated by crowded, elongated nuclei and tumor giant cells.

structure of the tumor is largely neurinomatous, radical amputation is indicated. In both of these groups of tumors just mentioned, the prognosis and indication for treatment differ markedly from primary sar-

coma of the bone in which the outlook for a cure is usually better than in tumors of the malignant neurogenic group, but worse than in neoplasms of the fibrosarcoma group.

OSSEOUS INVASION BY MISCELLANEOUS TUMORS OF CONNECTIVE TISSUE ORIGIN

In addition to the fibrosarcomas and neurogenic sarcomas producing skeletal involvement, there may be in rare instances a similar clinical picture caused by some unusual form of tumor of the connective tissue series.

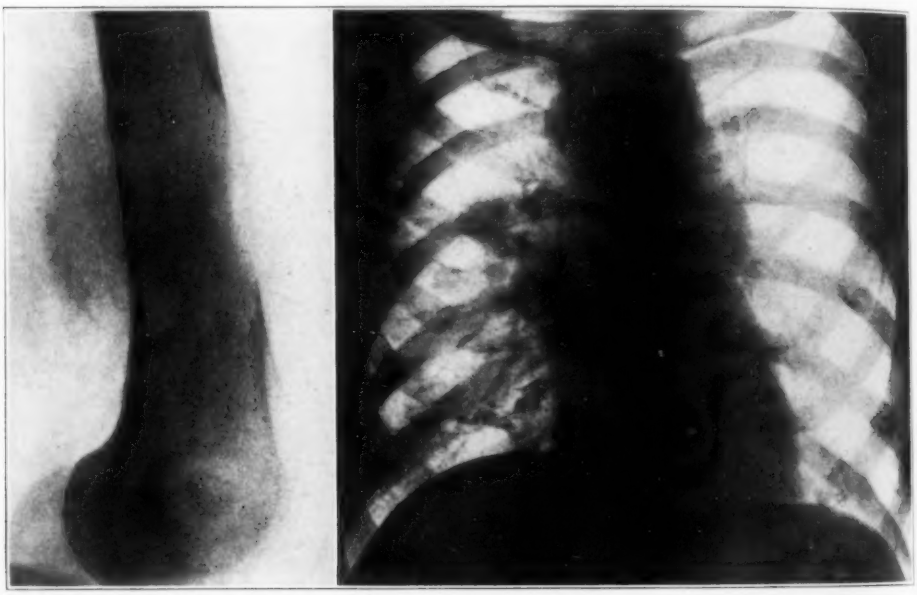

Fig. 39 (path. no. 25888).—A neurogenic sarcoma invading bone and producing pulmonary metastasis. Symptoms referable to the involved femur were present only five months, when the roentgenogram of the chest showed evidence of metastases. The patient died two months after the date of taking the films.

In a review of over seventeen hundred neoplasms involving the bone, after a complete study in which all cases with adequate data had been definitely classified, five such cases were found that could not be classed as either primary bone tumors or metastatic to the skeleton from other organs, and that were neither of the fibrosarcoma or neurogenic group. Three of these cases were classed as angiomatous, one as myosarcoma arising in the voluntary muscles and another as lipoma. These rare neoplasms of the bone are briefly reviewed here.

Angioma of the Bone.—While angioma of the bone is recognized by the Bone Registry of the American College of Surgeons as a definite entity, no verified angiomatous tumor is recorded in their collection. From the literature, particularly of the nineteenth century, it would appear that tumors of the hemangio-endothelial or hemangioma group are fairly common, but these older reports have in a large measure been discredited since they included many cases, either of carcinomatous metastases to bone, vascular forms of osteogenic sarcoma or neoplasms now recognized as belonging to the pathologic entity of Ewing's sarcoma or multiple myeloma (Howard and Crile [3]).

Fig. 40 (path. no. 25892).—A primary cavernous hemangioma of the upper end of the humerus, occurring in a white man, aged 25, following four years after trauma. The patient is living twelve years after a curettage and has full function of the arm (case of Dr. James Hitzrot). The roentgenogram illustrates the characteristic soap-bubble effect produced in the periosteal and cortical zones. There is no destruction in the marrow cavity.

Three benign hemangiomas of the bone (figs. 40-47) are recorded in the laboratory. One of these is of the cavernous type, occurring in a man, aged 25, in the upper end of the right humerus, with pain of two years' duration following trauma four years previously. The roentgenogram showed a peculiar soap-bubble effect extending into the periosteal zone and producing only slight erosion of the bone. At operation

3. Howard, W. T., and Crile, G. W.: A Contribution to the Knowledge of Endothelioma and Perithelioma of Bone, Ann. Surg. **42**:358, 1905.

a thin bone shell was found, and the tumor beneath had the appearance of an altered blood clot. The section showed a loose connective tissue stroma with dilated blood sinuses lined by endothelium and numerous peculiar connective tissue cells suggestive of sarcoma (see figs. 40-42). This case was reported by Dr. James M. Hitzrot [4] of New York,

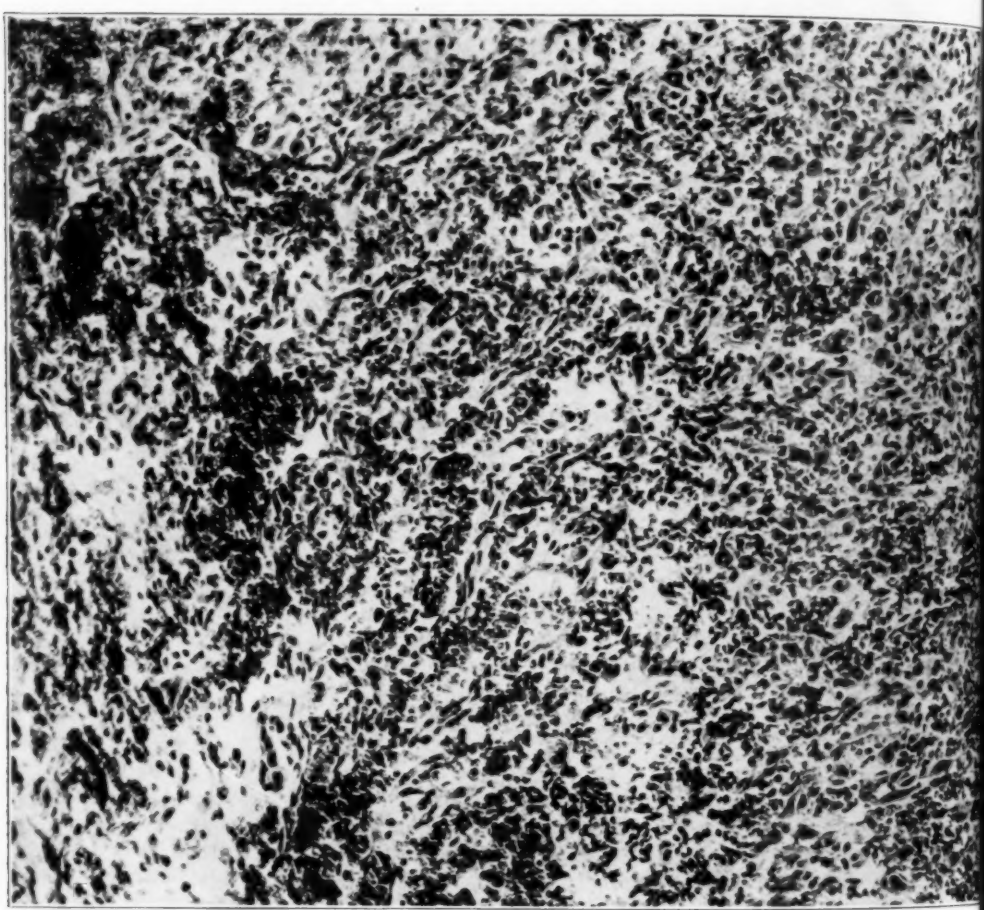

Fig. 41 (path. no. 25892).—Photomicrograph showing a cellular connective tissue area, with the development of a loose myxomatous substance and a lace-like branching of fibrous trabeculae (see fig. 40).

who appended a bibliography on vascular tumors reported in the older literature. Although only curettage was done in January, 1916, the

4. Hitzrot, J. M.: Haemangioma Cavernosum of Bone, Ann. Surg. **65**:477, 1917.

patient (who is a surgeon) was reported as leading an active life with full use of the arm in 1928.

The second case of angioma was of the capillary type (figs. 43, 44 and 45) and occurred in the lower end of the ulna in a white youth, aged 20, following an injury to the right wrist eight months previously. The tumor grew rapidly and was of soft consistency. The neoplasm had the same loose soap-bubble effect in the roentgenogram. The lesion was

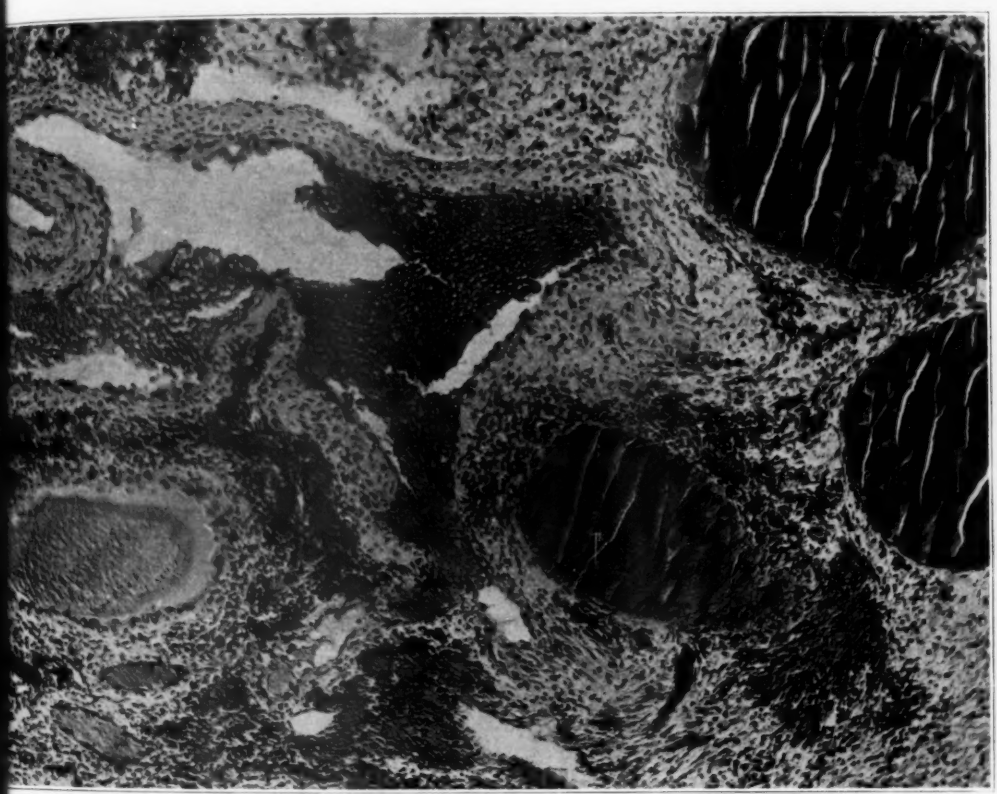

Fig. 42 (path. no. 25892).—Photomicrograph showing an area with dilated blood spaces lined by endothelium, about which connective tissue elements are proliferating (see fig. 40).

resected in September, 1926, and in the gross was composed of numerous irregular hemorrhagic cavities embedded in a white fibrous substance. The sections showed a mass of dilated capillaries lined by endothelium and surrounded by young connective tissue cells embedded in adult fibrous tissue. The patient was last reported well in September, 1929, three years after operation.

The third case (figs. 46, 47 and 48) occurred in the lower end of the humerus of a colored man, aged 52, who had had indefinite rheumatic complaints, supposedly for fourteen years, and pain with dysfunction for twelve months. There was a definite history of trauma, occurring three years before observation. Motion of the elbow was limited. The roentgenogram showed the same loose soap-bubble effect in the subcortical and subperiosteal regions. A local excision was performed in 1911, and

Fig. 43 (path. no. 38952).—A case of primary capillary hemangioma in the lower end of the ulna occurring in a white youth, aged 20, following eight months after trauma. The patient is living three years after a resection. The roentgenogram shows the characteristic soap-bubble, expansile lesion on the shaft side of the epiphyseal line. (Compare with figure 40.)

the tumor was removed in one piece. The tumor tissue was friable and in some places mushy, but was not described as hemorrhagic. Under the microscope the tissue resembled very markedly the cellular areas in the cavernous type of hemangioma previously described. There were many areas in which dilated capillaries were surrounded by a single layer of endothelial cells. The patient was discharged from the hospital in good

condition, but all attempts to trace him thereafter were futile, and nothing is known of the ultimate result.

These three tumors form a small but strikingly uniform group. All occurred in adults over 20 years of age; there was a history of trauma in each case, with a duration of symptoms varying from eight months to two years, and all involved bones of the upper extremities. The roent-

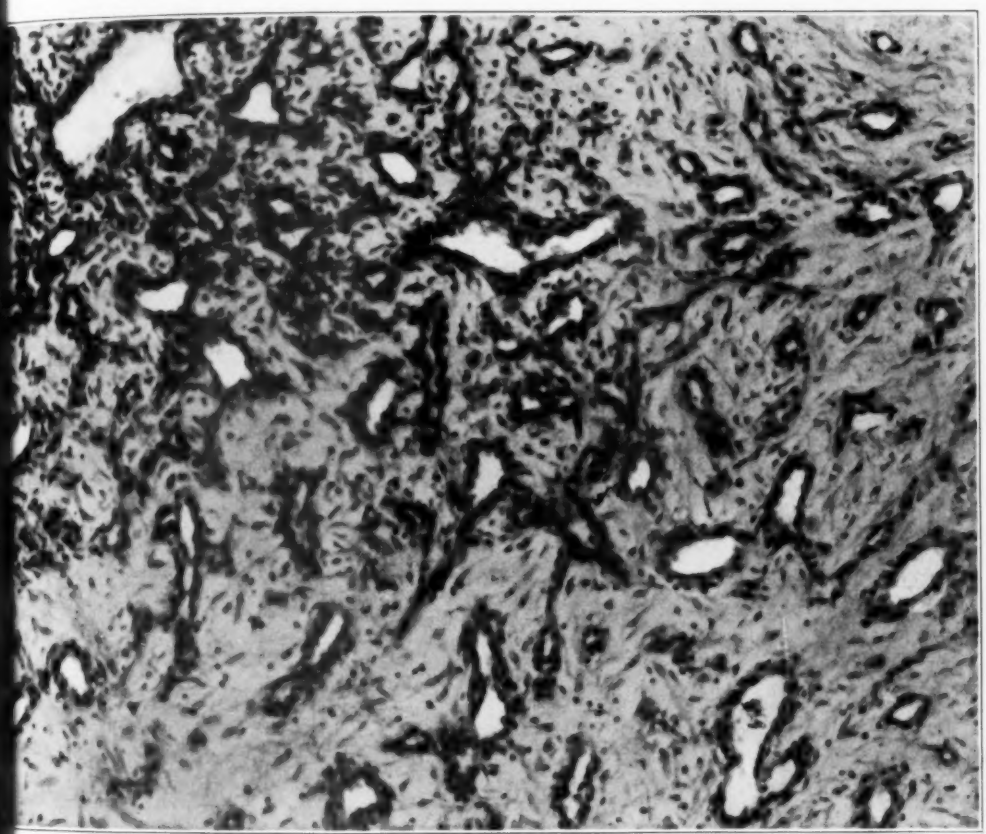

Fig. 44 (path. no. 38952).—Photomicrograph showing an area of dilated capillaries, lined by endothelium and surrounded by a loose connective tissue stroma (see fig. 43).

genogram in each case showed the same characteristic and unique soap-bubble effect. The coarsely multiloculated areas of rarefaction expand the shell of bone to paper-like thinness, but do not extend deeply into the medullary or cancellous spaces. The region of involvement is uniformly on the shaft side of the epiphyseal line and does not extend into the epiphysis. Microscopically, the three cases show histologic varia-

tions characteristic of the benign hemangiomas that are found in the soft parts or subcutaneous tissues. In no instance was death or metastases reported, although each of the patients had only a local operation. While included in this paper under tumors that involve bone by direct extension from the soft parts, it is not unlikely that the primary seat of the tumor was situated within the subperiosteal region of the bone in these cases.

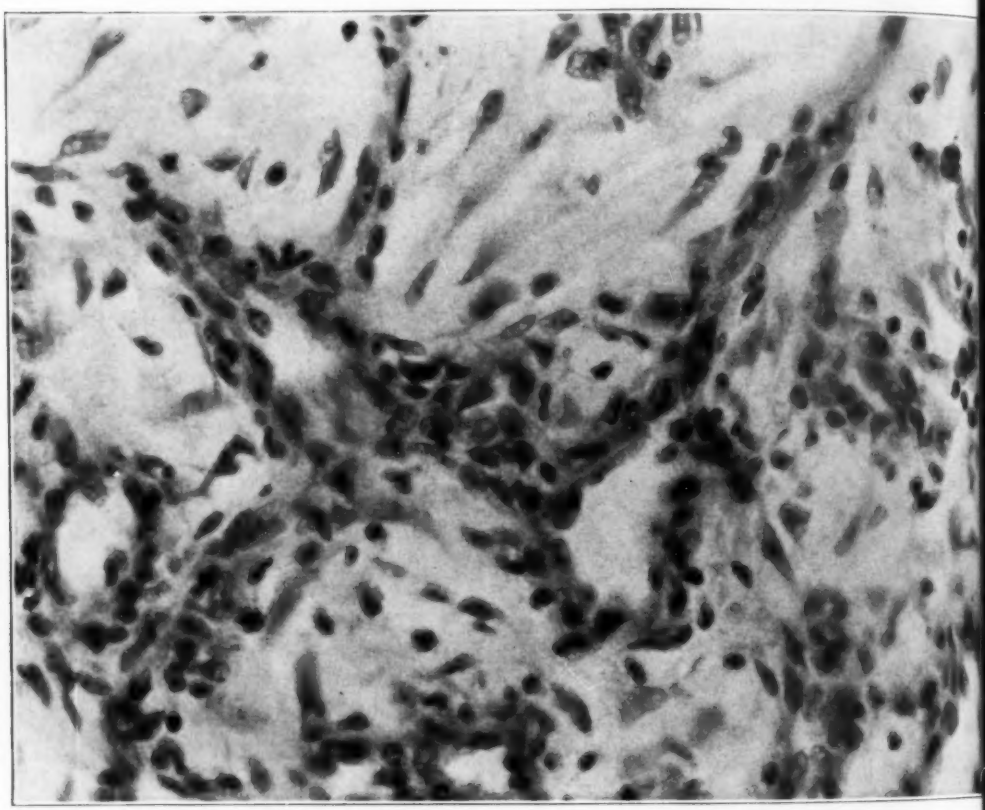

Fig. 45 (path. no. 38952).—High power photomicrograph of the area shown in figure 44. Note the tendency of capillary formation within the loose myxomatous syncytium.

It is important to note in studying the illustrations presented here that under the microscope these tumors were all predominantly of the connective tissue type containing numerous small spindle cells. They differ markedly from the usual hemangio-endothelioma (Kolodny[5])

5. Kolodny, Anatole: A Case of Primary Multiple Endothelioma of Bone, Arch. Surg. **9**:636 (Nov.) 1924.

reported in the literature in that they are single instead of multiple lesions, in that the regional lymph nodes are not involved, in that the tumors were not malignant and the cells are not of the epithelial-like type. The usual so-called hemangio-endothelioma reported are represented by four cases on file in this laboratory which were proved on careful study to be metastatic malignant pigmented moles without pigment, giving rise to multiple bone involvement and metastasizing to

Fig. 46 (path. no. 35221).—A case of primary capillary hemangioma in the lower end of the femur, occurring in a colored man, aged 52, following three years after trauma. The patient was discharged well after a local excision performed in 1911 and has not been traced since. The foamy, coarsely multiloculated appearance typical of benign angioma of bone is seen. (Compare with figures 40 and 43.)

regional lymph nodes. One of these cases is illustrated below (figs. 49 and 50).

Myosarcoma and Lipoma.—Two other cases are included here because of their rarity. One of these was a myosarcoma originating in the voluntary muscles in a white woman, aged 29, who had had recurrent

swelling following an injury to the lower end of the left femur four years previously. The swelling was removed by local operation in March, 1917, and the bone which was apparently slightly involved was scraped. A sinus persisted after the operation, and in the sinus a second tumor formed. This was excised in May, 1918, and had the appearance of an

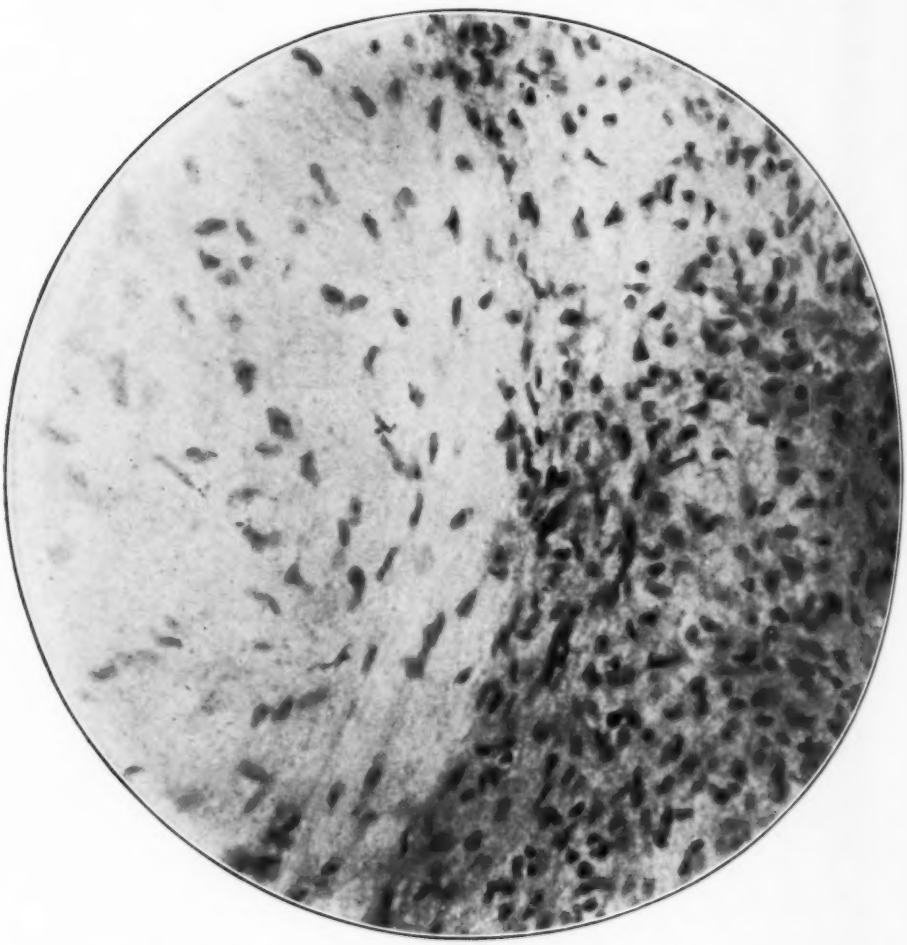

Fig. 47 (path. no. 35221).—Photomicrograph showing the loose connective tissue stroma and proliferation of connective tissue cells.

organized blood clot. A fungus-like growth again appeared in the wound, and in June, 1918, the leg was amputated. The gross specimen showed an apparently periosteal tumor extensively invading the underlying cancellous bone in the internal condyle of the femur.

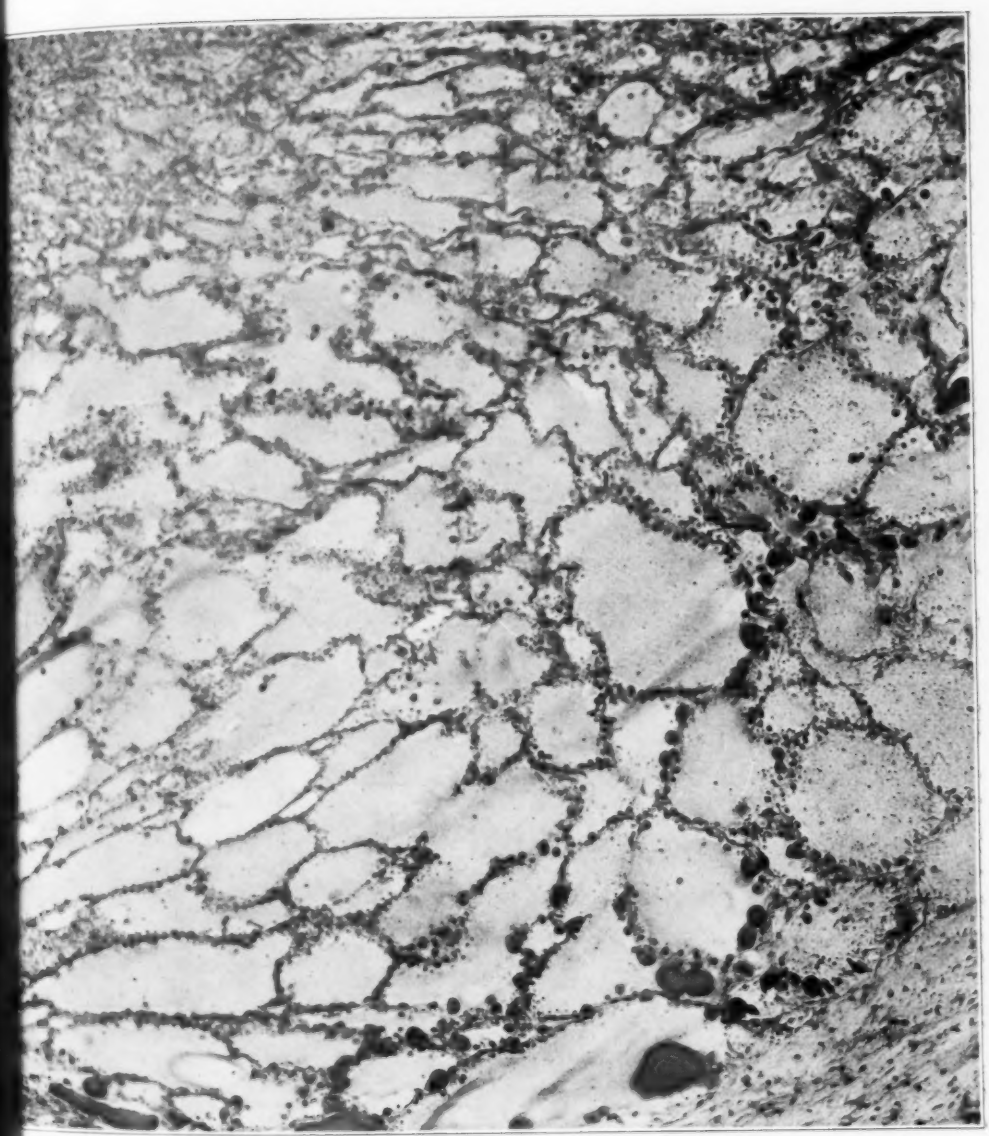

Fig. 48 (path. no. 35221).—An area of dilated capillaries.

The patient died three years and four months after the amputation with pulmonary metastases. Because of the relationship to bone and the fibroid reaction in the granulation tissue the tumor was originally classed as a fibrospindle sarcoma of the periosteum. However, under the microscope (fig. 51) a very distinct cellular picture composed of large cells with small nuclei enclosed in compartments formed by an eosin-staining reticulum was found. When cut in a longitudinal direc-

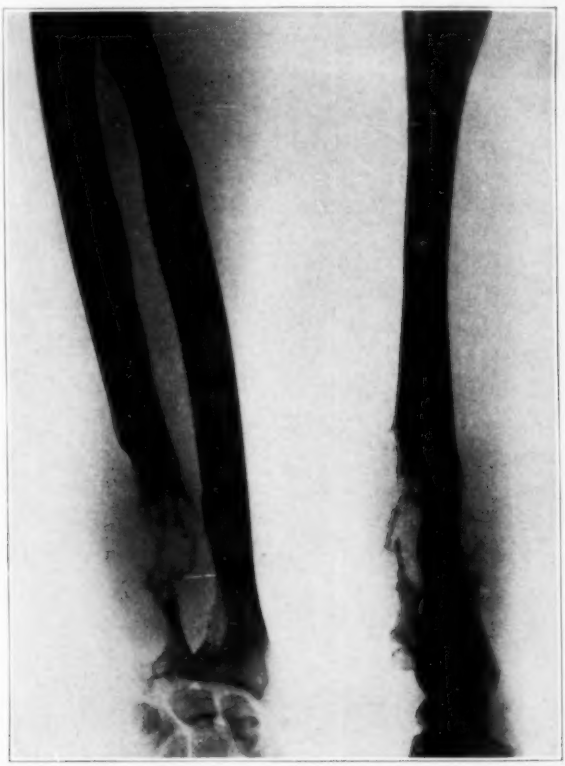

Fig. 49 (path. no. 48227).—A malignant pigmented mole metastasizing to bone and the regional lymph nodes.

tion, these cells had definite striations characteristic of voluntary muscle. The tumor was histologically identical with rhabdomyomas of other organs (heart, tongue, etc.) reported in the literature by Farber.[6]

The other case occurred in a white girl, aged 15, who had a swelling of one month's duration in the region of the knee joint. The roentgenogram showed a soft part swelling slightly eroding and roughening the

6. Farber, Sidney: Congenital Rhabdomyoma of the Heart, Am. J. Path. **7**:105, 1931.

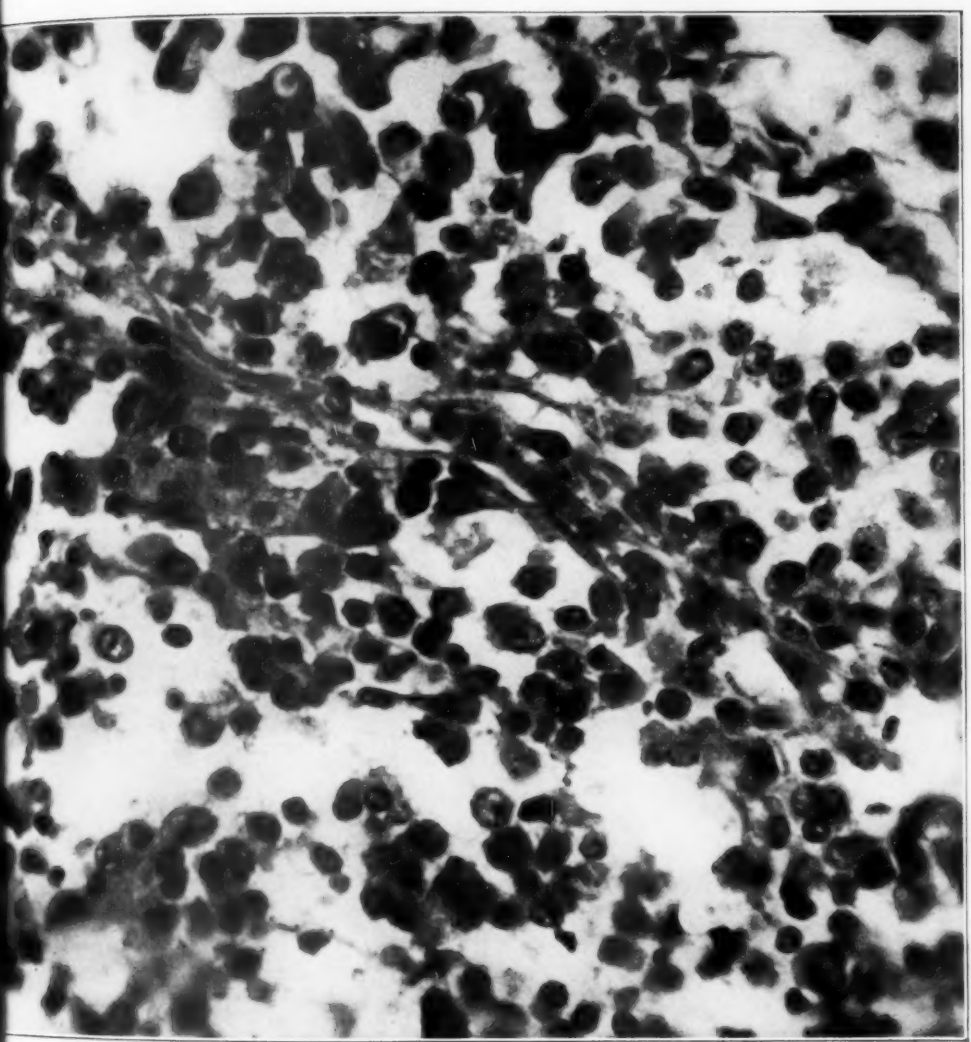

Fig. 50 (path. no. 48227).—Photomicrograph showing the cells of an epithelial-like character. No melanin pigment was seen in any of the sections, and the case was incorrectly diagnosed hemangioendothelioma. Similar mistakes are reported in the literature under such a diagnosis.

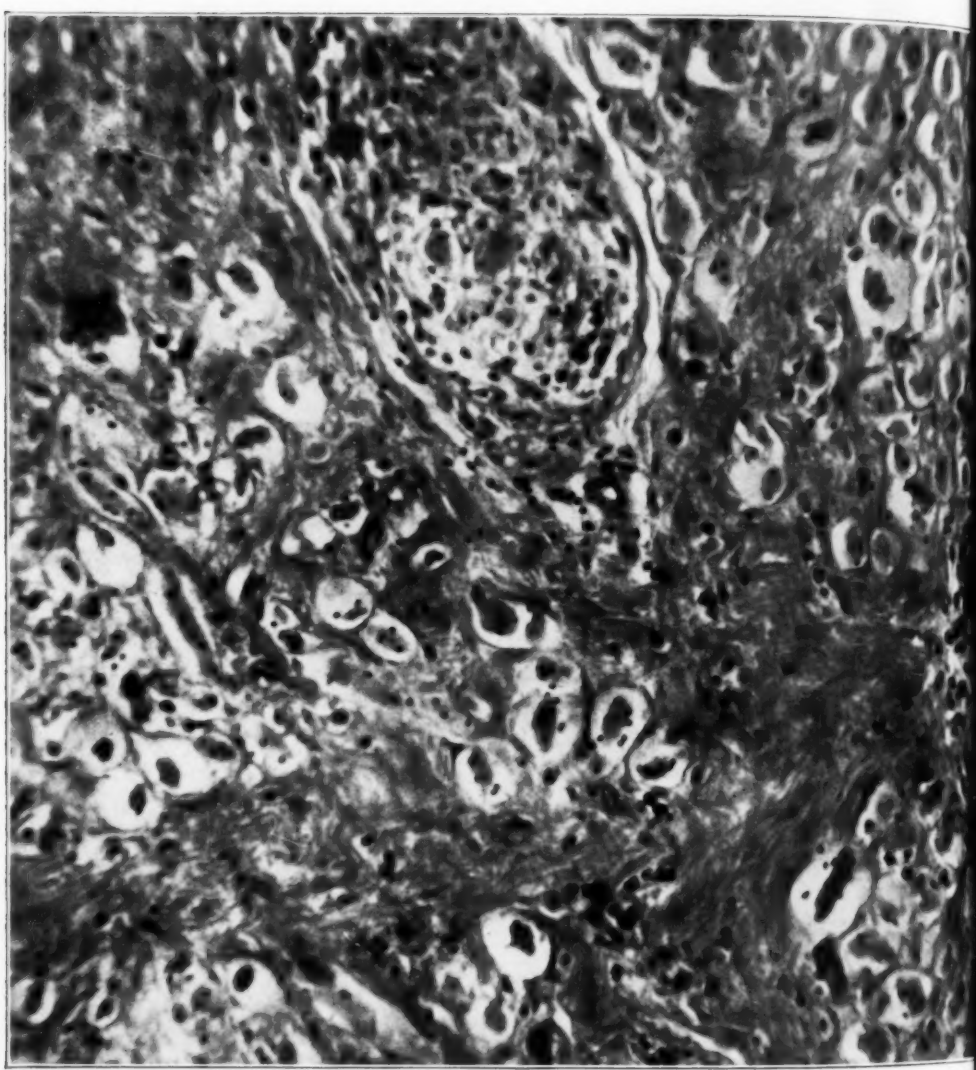

Fig. 51 (path. no. 23309).—Photomicrograph showing a sarcoma arising in the muscles around the lower end of the femur of a white woman, aged 29. The tumor invaded the bone, and the patient died of metastases three years after amputation. The photomicrograph shows the isolated muscle fibers with small nuclei cut at right angles and lying within small compartments (sarcolemma). Sections cut in the opposite direction show definite striations in the muscular fibers.

internal condyle of the femur. The sections showed a typical benign lipoma (figs. 52 and 53). A local operation was done, but the case is too recent to report the results of treatment. Two similar cases, which were distinctly benign, were recently reported by Edwin I. Bartlett,[7] although Stewart [8] reported instances of malignant bone involvement of supposedly liposarcomatous nature. The cases reported by Stewart, however, have a markedly different microscopic picture.

Fig. 52 (path. no. 44886).—A lipoma occurring in the knee joint and producing an erosion of the lower end of the femur. The soft part shadow and roughening of the external condyle of the femur are seen.

This small and miscellaneous group of connective tissue tumors involving the bone (nonosseous in origin and not metastatic in nature), although representing the odds and ends of a far larger collection of neoplasms primary in the bone, demonstrates the variety of conditions

7. Bartlett, Edwin I.: Periosteal Lipoma, Arch. Surg. **21**:1915 (Dec.) 1930.

8. Stewart, Fred W.: Primary Liposarcoma of Bone, Am. J. Path. **7**:87, 1931.

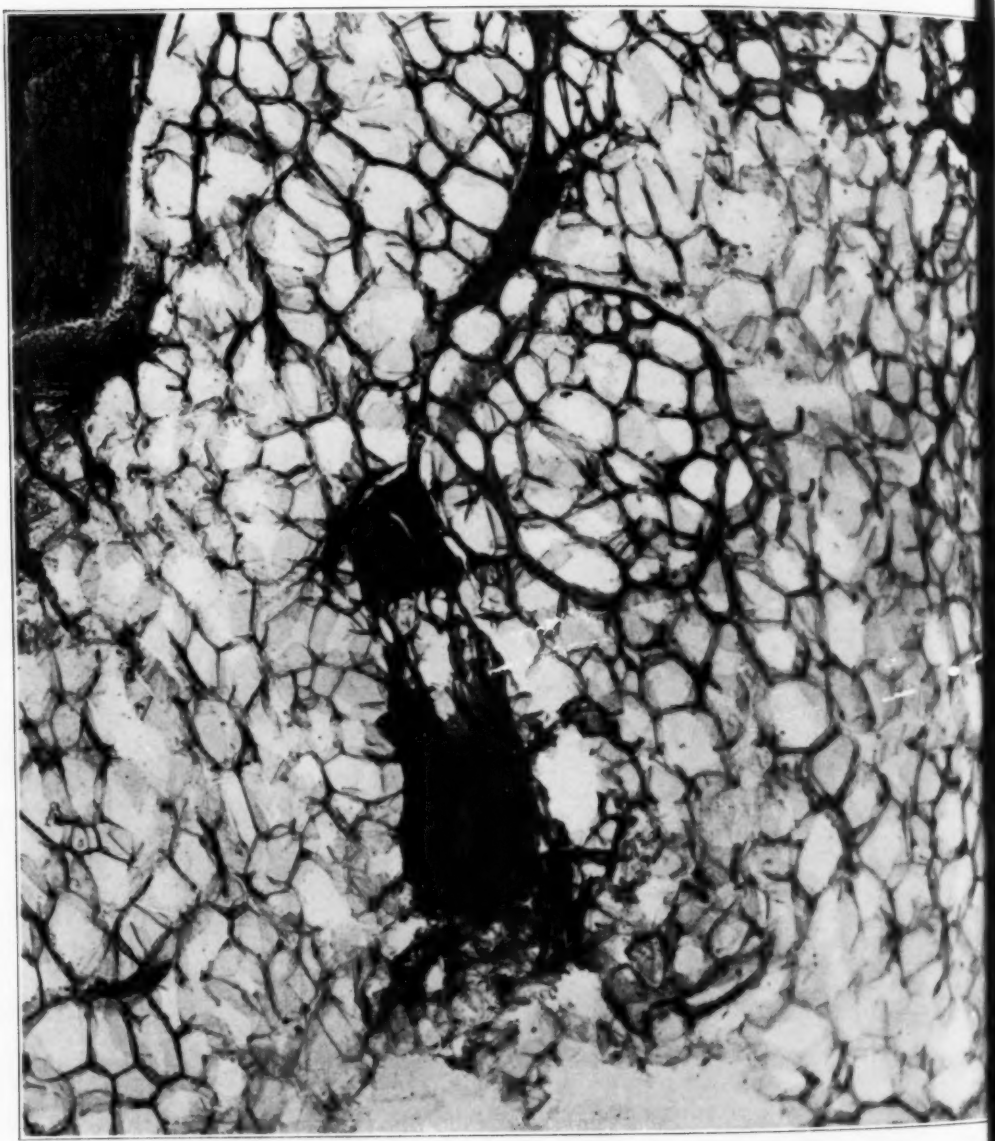

Fig. 53 (path. no. 44886).—Photomicrograph showing adipose tissue enclosed by coarse fibrous trabeculae.

under which neoplastic invasion of the skeleton may occur. When taken in conjunction with the fibrosarcoma and neurogenic sarcoma groups discussed in the early part of this paper, they indicate the importance of identifying pathologically the type of tumor producing the osseous involvement.

In all the cases reported in this paper, the initial diagnosis was usually incorrect, and even after the customary pathologic examination, the tumor was in most instances incorrectly classified. The prevalent tendency is to regard these neoplasms erroneously as primarily osteogenic, or to judge them too indiscriminately as fascial sarcoma. As a result, the prognosis and mode of treatment is often on an insecure and improper basis.

From the present study, however, it is clear that each of the various entities warrants individual treatment. In fibrosarcoma invading bone, not of the oat cell type, an attempt to eradicate the disease locally is justifiable, but amputation should be resorted to promptly after recurrence. In the oat cell type, primary amputation when possible is advocated. In the neurogenic sarcoma group producing osseous involvement, primary amputation is the treatment of choice. In angiomas of the bone, local excision is warranted, preferably reinforced by irradiation since this type of tumor when occurring in the soft parts or subcutaneously gives indication of radiosensitivity. For lipomas, local operation is indicated, and in rhabdomyoma, amputation.

A COMPLICATION OF TARRY LUTEAL CYSTS*

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The literature on blood cysts of the ovary presents a fascinating study, particularly the literature of recent years, and especially that relating to the tarry and the chocolate cysts. The greatest debate has been waged concerning the cysts that have an epithelial lining.

In 1899, Russell [1] described an ovarian cyst and said that it arose from an aberrant remnant of Müller's duct. In 1905, Pick [2] reported a case of adenoma endometrioides ovarii. Since then considerable interest has been taken in these structures. In 1917, Blair Bell [3] suggested the term endometrioma, and Sampson has since used the term endometriosis.

In 1920, Sampson [4] gave his classic description of the "perforating chocolate cysts" of the ovary. He suggested that they arose by the transplantation of pieces of uterine mucosa through the fallopian tubes on to the surface of the ovary, where they grew and developed.

During the last decade, an extraordinary interest in the condition has become manifest. The literature is colossal, and though many of the references are case reports only, several hypotheses have been advanced. It is unnecessary to discuss these in detail, since they have already been discussed by several writers.

The uterine origin of the cysts seems to have completely captured the imagination of most workers, and the hypothesis seems to be considered fact, although the evidence is circumstantial.

While attention has been focused on this aspect of the tarry cysts, another point of view has been considered by other investigators, who have showed that many of the tarry cysts are of luteal origin. As

* Submitted for publication, April 22, 1931.

1. Russell, W. W.: Aberrant Portions of the Müllerian Duct Found in the Ovary, Bull. Johns Hopkins Hosp. **10**:8, 1899.

2. Pick, L.: Ueber Neubildungen am Genitale bei Zwittern, nebst Beiträge zur Lehre von den Adenomen des Hodens und Eierstockes, Arch. f. Gynäk. **76**:191, 1905; Ueber Adenome der männlichen und weiblichen Keimdrüse bei Hermaphroditismus verus und spurius, Berl. klin. Wchnschr., 1905, no. 17, p. 502.

3. Bell, W. Blair: Principles of Gynaecology, London, Baillière, Tindall & Cox, 1917.

4. Sampson, J. A.: Perforating Hemorrhagic (Chocolate) Cysts of the Ovary (Résumé), Am. J. Obst. & Gynec. **11**:526, 1921.

long ago as 1898,[5] it was demonstrated that luteal cysts may develop a heterotopic lining of epithelium, and a similar lining was demonstrated in many of the tarry luteal cysts. The question that arises immediately is, Are these two varieties of tarry cysts different, or are they identical? In a recent paper, I[6] attempted to show that the similarities between the cysts, the endometriomas (or endometriosis) and the tarry luteal cysts are remarkable. The inference is that they are identical. This is, however, not yet proved. The problem will be discussed further in another paper. The two cases of tarry luteal cyst reported here illustrate a complication that is thought generally to be characteristic of endometrioma. Similar examples were reported by Brakeman[7] and Shaw,[8] and a related condition was referred to by Johnson,[9] but since so much emphasis has been laid on the endometriomas and their complications, no opportunity of assisting in a restoration of balance of opinion should be lost.

REPORT OF CASES

CASE 1.—B. E., unmarried, aged 27, complained that she had not been feeling well for the seven months before examination. At first she had merely felt tired in the evening. Two months before being examined, she had an attack of "influenza" associated with pains all over the body and persistent vomiting for five days. Her tongue was coated, and the abdomen was swollen, but there was no localized abdominal tenderness. She was constipated, and the feces were offensive. She recovered, but on having a similar attack, came to the hospital for treatment. Her menstrual history was normal.

On examination, she was somewhat pale. There was a slight, generalized soft swelling of the abdomen with tenderness in both iliac fossae. Pelvic examination disclosed a small mass in the right fornix and a thickening of the left fornix and pouch of Douglas.

On operation, a large number of adhesions of the omentum were found to the back of the uterus. There were also a number of cysts, varying in size from minute structures to one or two which were from 1 to 1½ inches (2.5 to 3.8 cm.) in diameter. The cysts contained a yellowish fluid, and two or three contained old blood. A number of small tarry cysts were found in the right ovary. There were dense adhesions in the pouch of Douglas. The ovary, tube and omentum were removed.

Pathologic examination of the right ovary, which was twice as large as normal, disclosed a number of cysts; some contained blood, and on the walls of two was a marked yellow layer. Microscopically, the walls showed luteum-like cells in various stages of retrogression. None of the cysts showed a heterotopic epithelial

5. Fraenkel, L.: Der Bau der Corpus-luteum Cystem, Arch. f. Gynäk. **56**:355, 1898.

6. King, E. S. J.: The Morphological Similarity of Certain Luteal Cysts and Endometriosis of the Ovary, Surg., Gynec. & Obst. **45**:1, 1930.

7. Brakeman, O.: Beitrag zur Klinik und Pathologie der Teercysten des Eierstockes, Arch. f. Gynäk. **129**:632, 1927.

8. Shaw, W.: Some Pathological Forms of the Corpus Luteum, J. Obst. & Gynæc. Brit. Emp. **34**:300, 1927.

9. Johnson, W. C.: Peritoneal Reaction to Contents of Ruptured Hemorrhagic Cyst of the Ovary, Proc. New York Path. Soc. **23**:142, 1923.

Fig. 1 (case 2).—The bilocular tarry luteal cyst removed from the site of the right ovary.

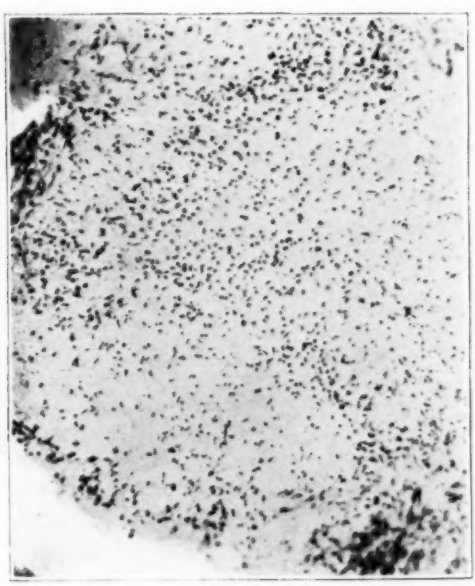

Fig. 2 (case 2).—Photomicrograph of a portion of the wall of a cyst which was removed from the site of the left ovary. Luteal cells are present; × 110.

Fig. 3.—Photomicrograph of another portion of the wall showing an epithelial-lined "gland" communicating with the cavity of the cyst; × 110.

Fig. 4.—Photomicrograph from the secondary nodule in the wall of the sigmoid colon; epithelial-lined spaces and a blood cyst are present; × 35.

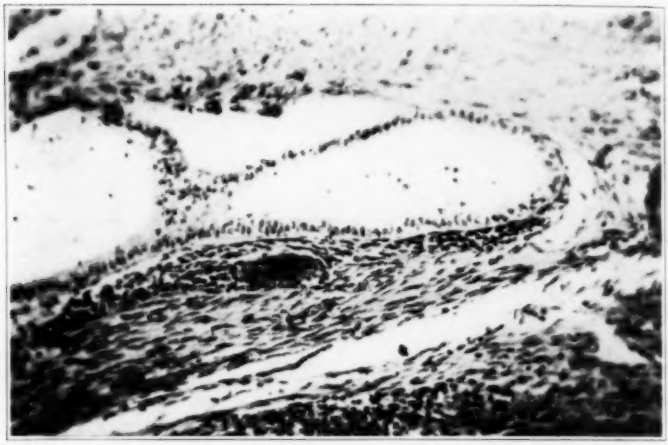

Fig. 5.—Higher power view of portion of one of the "glands" shown in figure 4; × 110.

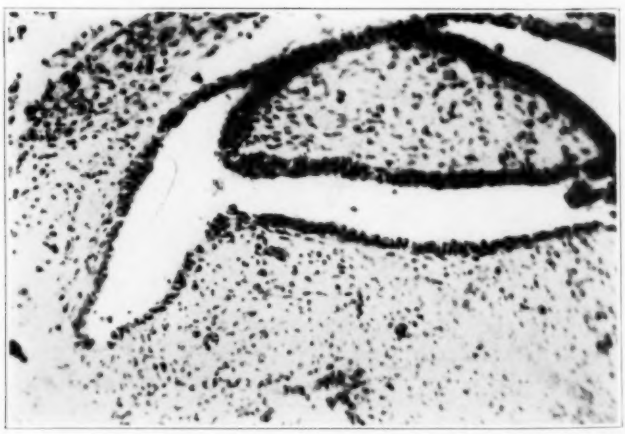

Fig. 6.—Another portion of the same nodule showing the nature of the epithelium; × 110.

lining. The cysts in the omentum were thin-walled and showed cells in the walls similar to those in the luteal cysts of the ovary, but in this case they were probably phagocytic. In one or two of the cysts there was a lining of columnar cells. The dense tissue in the rectovaginal septum also showed some of these cells.

CASE 2.—J. M., aged 17, was admitted to the hospital with a complaint of pain in the hypogastric region of four days' duration occurring every fortnight. This pain commenced when she was 14 years of age. There had been an absence of menstrual flow. The patient had been partially blind and deaf in one ear for years.

On examination, it was found that the sight was definitely impaired owing to interstitial keratitis. Punched-out ulcers were present on both legs. The chest was normal. There was a large oval midline tumor rising out of the pelvis and extending to just above the umbilicus.

On pelvic examination, the cervix could not be felt. The uterus was in the normal position, not enlarged and adherent to the anterior tissues.

Fig. 7.—Photomicrograph taken from the same section showing an epithelial-lined space and a small "gland" space. Calcification is present; × 75.

Under an anesthetic, vaginal examination with a speculum showed a normal mucous membrane but no cervix uteri in the vault. There appeared to be a fold of mucous membrane in the region of the uterus. A sound was passed in this region, and about 2 ounces (59 cc.) of brownish fluid escaped.

Later, an exploration of the abdomen was performed. The large swelling found clinically proved to be a bilocular blood cyst of the right ovary. This was removed, together with the fallopian tubes.

The cyst of the ovary was ovoid, measuring 10 by 9 cm. in diameter. On section, it was found to contain chocolate-colored material and to be bilocular (fig. 1). The walls were 5 mm. in thickness.

Microscopic section of the wall showed that the cysts were luteal. Luteal cells of a somewhat atypical character were present in most portions of the wall. There was no epithelial lining. The fallopian tubes showed some aplasia of the epithelium.

Six months later, the patient returned to the hospital, having had pain during the intervening period. There had been no vaginal discharge at any time.

Examination disclosed tenderness in both iliac fossae, and in the midline in the suprapubic region. On pelvic examination, a mass could be felt in the pouch of Douglas, extending toward the left side. This was diagnosed as a cyst of the left ovary.

On operation, the uterus was found to be of about normal size. The right ovary was slightly enlarged and the site of a blood cyst. There was a small blood cyst on the wall of the sigmoid colon.

The uterus, right ovary and nodule on the sigmoid colon were removed.

The uterus was slightly larger than normal and globular. It contained a small amount of tarry material. The site of the previous attachment of the fallopian tubes was intact.

Microscopically, the endothelium showed considerable aplasia.

The ovary was enlarged, measuring 2 by 2 by 1½ inches (5 by 5 by 3.8 cm.) in diameter. It contained a number of blood cysts. Microscopically, these were luteal cysts in various stages of retrogression; in their walls were epithelial "glands," and in some places the inner surface was lined by tall columnar epithelium.

A nodule from the sigmoid colon was irregularly spherical and measured 1.5 cm. in diameter. On section, it was found to contain a number of cystic spaces filled with blood. Microscopically, it consisted of a number of small blood cysts lined with tall columnar epithelium, and in the wall beneath the epithelium there was a "stroma" of small round cells and spindle cells. In many places there were "glands." Hematogenous pigmentation was present in the tissue in some places.

COMMENT

The discovery of peritoneal cysts secondary to tarry or chocolate cysts of the ovary usually leads to a diagnosis of endometriosis.

The observation made by several workers that tarry cysts of luteal origin may also produce such secondary cysts renders a thorough examination of any blood cyst of the ovary essential before a definite diagnosis may be made. It also raises the question whether an unquestioning acceptance of the uterine origin of the "endometrial" cyst of the ovary is not a perilous attitude.

In both of the cases reported in this paper, the nature of the ovarian cysts was demonstrated conclusively by the discovery of luteal tissue in their walls. Not all cysts of the luteal type are easy to diagnose, e. g., the corpus albicans cysts, in which the luteal cells have been replaced by hyaline tissue. In cases 1 and 2, however, this difficulty does not arise.

Another important point was the relationship of the columnar epithelium present in case 2 to the cavity of the luteal cyst. Luteal bodies are of common occurrence in the ovary, and the presence of both the luteal tissue and the endometrium-like epithelium could conceivably have been accidental or incidental. Serial sections, however, showed that the columnar epithelium lined, in part, the wall of the luteal cyst.

In a number of places crypts were present in the wall, and the epithelium lining these was cut across, giving the appearance of "glands." Fortunately, a number of these were cut longitudinally so that their continuity with the epithelium lining the wall of the cyst was indisputable. In some sections, however, there was no evidence that the "glands" were related to the epithelium in the luteal cyst, and in the absence of the evidence obtained from serial sections they would have been labeled "endometrial."

In tarry luteal cysts of the ovary only a marked reaction of the peritoneum to the spilt material may occur, as has been described by some writers,[10] but in other cases epithelial-lined cysts may develop.

The effect on the peritoneum of the spilling of the contents of the cysts, with the development of secondary epithelial-lined cysts in the cases described, is particularly worthy of note, since the dense fibrous tissue reaction associated with the rupture of "endometriomatous" cysts has frequently been observed, but the fibrosis associated with tarry luteal cysts has been recognized only occasionally.

One important feature in case 2, from the point of view of Sampson's hypothesis, was the condition of the uterus. There was atresia of the os uteri, and therefore obstruction to the outflow of menstrual blood. This was an ideal case for retrogressive flow through the fallopian tubes or veins. There was, however, no evidence that blood was flowing through the tubes. These were removed after the first operation, and yet cysts developed in the other ovary and on the sigmoid colon.

More direct evidence was present in the aplastic condition of the endometrium and also in the luteal nature of portions, at least, of the walls of the cysts.

10. Brakeman (footnote 7). Johnson (footnote 9). Shaw (footnote 8).

RETROPERITONEAL LIPOMA

REPORT OF A CASE IN WHICH THE TUMOR WEIGHED TWENTY-TWO AND ONE-HALF POUNDS *

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AND
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Several years ago Greensfelder and one of us (Dr. Bettman) reported a case of retroperitoneal lipoma [1] and reviewed the literature to that date. We found that von Wahlendorf [2] had collected 166 cases of retroperitoneal lipoma, and that at about the same time Lecéne [3] had reported 113 cases of solid paranephric tumors of which many were lipomas. Besides the cases of these two authors we were able to collect 16 other cases: Masson and Horgan,[4] 12 cases; Holmes,[5] 1 case; Hirsch and Wells,[6] 1 case of their own and 1 case of McConnell's,[7] and Heppner,[8] 1 case. Most of these cases had been published after von Wahlendorf's article went to press. At this time we wish to present another case of our own and to review briefly 11 cases that have appeared in the literature since the publication of our last article.

REPORT OF CASE

History.—A man, aged 40, entered the hospital on April 17, 1930, because of an abdominal enlargement of from six to seven months' duration, associated with weakness and heart burn. For fifteen years he had had "stomach and bowel

* Submitted for publication, May 19, 1931.

* From the Surgical Service of the Michael Reese Hospital.

1. Greensfelder, L. A., and Bettman, R. B.: Retroperitoneal Lipoma, Surg., Gynec. & Obst. **37**:468 (Oct.) 1923.

2. von Wahlendorf, A. L.: Ueber retroperitoneale Lipome, Arch. f. klin. Chir. **115**:751 (May) 1921.

3. Lecéne, P.: Les tumeurs solides para-néphritique, Rapport assoc. franç. de chir., XXVIII Congress, Paris, Oct. 10, 1919.

4. Masson, J. C., and Horgan, E. J.: Retroperitoneal Lipomata, S. Clin. North America **1**:1451, 1921.

5. Holmes, Walter R.: Retroperitoneal Perirenal Lipomas, J. A. M. A. **75**: 1065 (Oct. 16) 1920.

6. Hirsch, E. F., and Wells, H. G.: Retroperitoneal Liposarcoma, Am. J. M. Sc. **159**:356 (March) 1920.

7. McConnell: Recurrent Liposarcoma of Kidney, J. M. Research **19**:225, 1908.

8. Heppner, E.: Large Retroperitoneal Lipoma with Sarcomatous Degeneration, Ztschr. f. Urol. **14**:14, 1920.

trouble" which consisted of attacks of abdominal cramps and frequent (from six to seven times daily) watery stools. He had noticed a gradual enlargement of his abdomen during the last half year. He had had "dizzy spells" and lately had been slowly getting weaker. He was able to continue work, however, until almost the date of admission to the hospital. He volunteered the surprising fact that although his abdomen was so definitely increasing in size he was gradually losing weight, 20 pounds (9 Kg.) in the last five years. On careful questioning, he admitted vague symptoms best described as abdominal discomfort.

Fig. 1.—Photograph of the tumor and attached kidney immediately after operation (posterior surface). Note the relative size of the mass as compared to the attached kidney and 8 inch retractors.

Examination.—Examination revealed a thin white man weighing 156 pounds (70.8 Kg.), with a protruding abdomen in startling comparison to his general emaciation. His complexion was pasty. His cervical, axillary, epitrochlear and inguinal lymph glands were palpable but small, firm and distinct. Examination of the chest revealed no abnormality other than that the base of the right lung was about 2 inches (5 cm.) higher than the left. The heart was slightly enlarged. The extremities were normal. There were no varicose veins, and the ankles did not swell on standing.

The abdomen was well rounded and on first sight suggested the distention occasionally seen in a case of marked paralytic ileus. On palpation, however, it was readily ascertained that the distention was due to the presence of a hard, firm, smooth mass apparently directly under the muscles. The mass projected from under the entire right costal margin and extended to the midline from the xyphoid to the umbilicus. The upper and lower left portions of the abdomen, as well as a very small area in the lower right quadrant, were softer on palpation and tympanitic on percussion and apparently contained intestines. In the midline of the abdomen there seemed to be a definite groove in the mass. The mass in the left side felt exactly the same as it did on the right and apparently was part of the same tumor. No mass could be palpated in the left lumbar region. Rectal examination was negative except for a slight prostatic hypertrophy. There were no abdominal varices and no scrotal varicocele.

Roentgen examination showed that practically the entire gastro-intestinal tract was crowded over to the left side of the abdomen, while the entire right side and a portion of the left were filled with a mass which cast a dense homogeneous shadow. An intravenous pyelogram showed the right kidney and ureter to be displaced downward and inward. Catheterized specimens of urine from both ureters were normal. The temperature, respiration and pulse rate were normal. The blood count was normal as to both numbers and types of cells.

Diagnosis.—The vagueness of the symptomatology, the length of duration of the abdominal tumor with the apparent slight discomfort and but recent loss of strength and particularly the roentgen picture immediately recalled to our minds the case previously reported. We felt that a tumor of the kidney could be ruled out by the form and position of the tumor, and by the groove at about the midline where it extended over to the left side of the abdomen. This groove we thought could best be explained by pressure of the mesenteric vessels in a retroperitoneal tumor. We thought that a mesenteric cyst could be ruled out because of its apparent origin in the right flank, its firm consistency and its immobility. A primary malignant condition could be discounted because of the great discrepancy between the size of the tumor and the lack of symptoms. The most likely benign, retroperitoneal tumor of such size, arising apparently from the right perirenal region, of the shape and consistency of this tumor, apparently crossing the midline of the abdomen behind the mesenteric vessels and giving as few symptoms as this tumor, would be a retroperitoneal lipoma. We therefore made the diagnosis of a retroperitoneal lipoma and advised operation.

Operation and Course.—Operation was performed under spinal anesthesia, 250 mg. of procaine hydrochloride being used. A transverse incision was made starting in the midline a few centimeters above the umbilicus and extending laterally and slightly upward into the right flank, cutting successively through skin, subcutaneous tissues, fascia and muscles. The peritoneum was carefully opened, and a large, firm, fatty tumor presented. It was immediately recognized that a larger opening was needed, and so the incision was extended to the left side in a similar manner as to the right. Even then the opening was not sufficient until a perpendicular incision was made in the midline extending upward for 2 or 3 inches (5 or 7.6 cm.). It could now be seen that this large tumor, apparently a typical lipoma, occupied the greater part of the intra-abdominal cavity. It was not adherent anteriorly. It was covered with a venous network, some of the veins being the size of the little finger. What seemed to be the anterior portion of the capsule was in fact the posterior peritoneum. The intestines were crowded over to the left, as shown by palpation and the x-rays, and the root of the mesentery had caused a definite groove at the midline.

The posterior peritoneum was incised near and parallel to the crowded over, ascending colon as in mobilizing the ascending colon in the operation of colectomy. The tumor was then freed as much as possible by blunt dissection. Great care was taken at the portion of the tumor in which the mesenteric vessels lay, lest they be cut, an accident which accounts for a large percentage of the primary mortality recorded in the literature. After this had been done the dissection was carried over into the flank. The ureter was found lying in a deep groove in the tumor. The kidney was almost completely surrounded by the mass, while the renal artery and vein seemed entirely buried. It was felt that the technical difficulties of freeing the vessels were so great that the risk involved was not justifiable in view of the perfect function of the opposite kidney, so that the renal artery and vein were

Fig. 2.—Anterior surface. Note the many large collapsed veins.

firmly ligated and cut close to their junction with the aorta and vena cava, and the kidney was removed with the tumor. The ureter was ligated close to the bladder and cut. The main blood vessels to the tumor seemed to arise from the perirenal region. These were clamped and cut, and the tumor was removed. A stab wound for drainage purposes was made in the right flank. The cut edge of the posterior peritoneum, close to the ascending colon, was sutured into the flank, closing the raw surface left after the removal of the tumor and bringing the colon back approximately to its normal position.

A transfusion of 250 cc. of whole blood was given before and after the operation. The patient left the operating table in none too good a condition, but promptly rallied and made a speedy and uneventful recovery.

Pathologic Changes.—The pathologic report made by Dr. Otto Saphir was as follows: "The specimen consists of tumor with attached kidney and ureter, measuring 50x25x25 cm. in its greatest diameters and weighing 22½ lbs. The tumor in most portions has the appearance of fat. In some portions it is fairly firm in consistency; in others it is soft and gelatinous. In these latter portions the tumor appears to be degenerating. One portion of the tumor shows the fatty appearance to be somewhat obscured by a dull brown color. The consistency here is fairly firm. The entire tumor is covered by a thin membrane. The kidney is apparently normal."

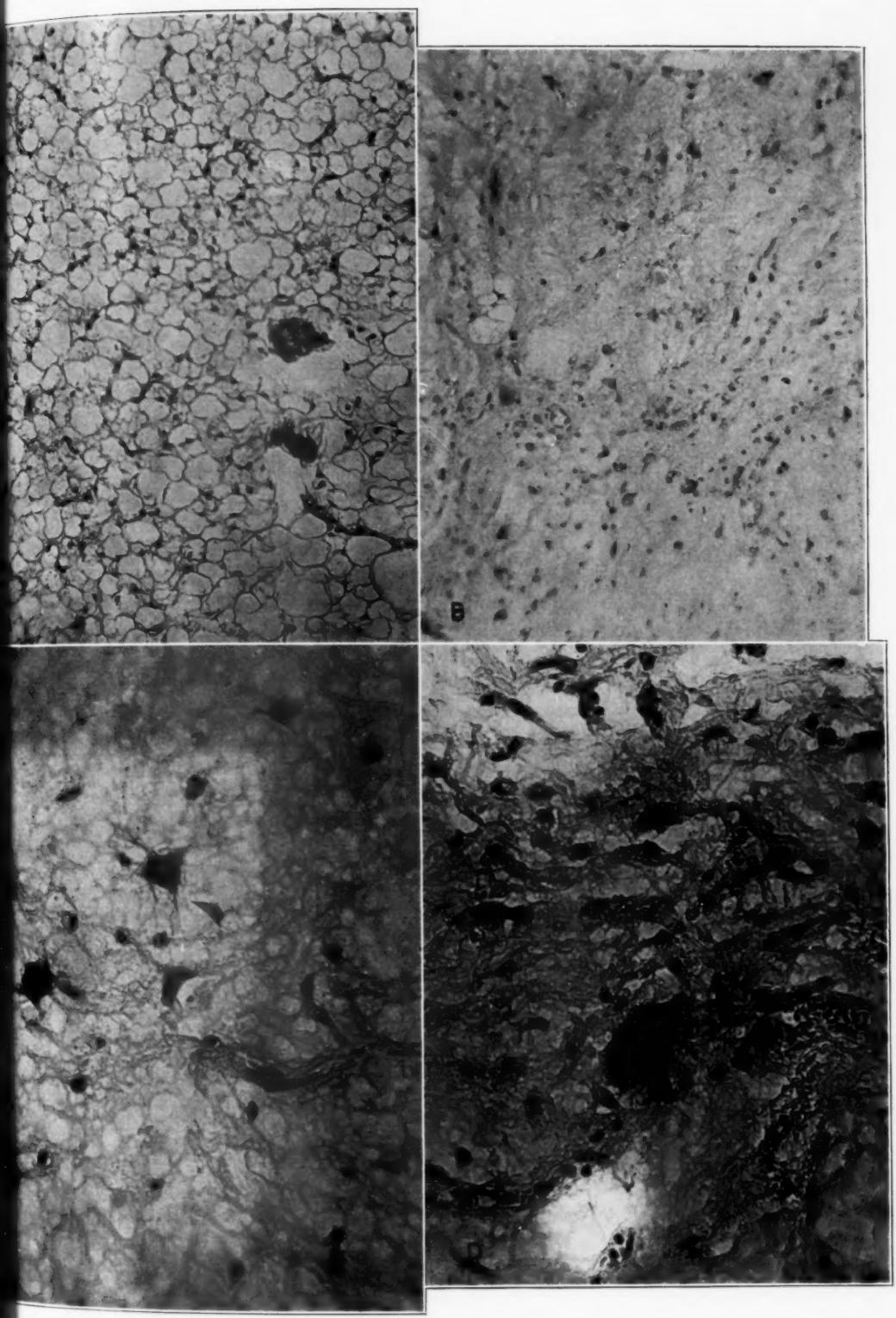
Microscopic Observations.—The microscopic report was as follows: "Some of the sections reveal a marked new formation of fat tissue, with many small indistinctly outlined signet-shaped cells. Other sections show throughout the fat tissue a moderate number of spindle-shaped cells and connective tissue fibers extending in various directions. Other fields show the presence of a pink-stained mucinous material with many stellate-shaped cells. Other portions again reveal many lymphocytes and endothelial cells which are found infiltrating the connective tissue fibers and fat tissue. Sections reveal that the fat tissue constitutes the largest portion of the tumor."

Fig. 3.—The patient two weeks after operation. The incision is marked with mercurochrome-220 soluble so as to photograph more clearly. Ten months after operation the patient was found working at his trade as an iceman and carrying heavy blocks of ice up three and four flights of stairs without discomfort and with no signs of hernia.

In our former article we briefly reviewed the literature up to that date. Since then we have found the following cases:

Stratton [9] reported a case of retroperitoneal lipoma in a woman aged 39. The tumor was situated in the left side of the pelvis. It

9. Stratton, F. A.: Retroperitoneal Tumors, Wisconsin M. J. **22**:260 (Nov.) 1923.



. 4.—*A*, lipoma. Note the fat cells. Hematoxylin-eosin preparation; × 128. *B*, myxomatous degenera- Hematoxylin-eosin preparation; × 120. *C*, myxomatous degeneration. Note the stellate cells with processes. oxylin-eosin preparation; × 380. *D*, lipoma with myxomatous degeneration and multinucleated cells. oxylin-eosin preparation; × 380.

weighed 9¾ pounds (4.4 Kg.). The pathologic diagnosis was fibromyxolipoma. A year previously a small lipoma had been removed from the shoulder.

Johnson [10] reported a case of pure lipoma in a man. The tumor was on the right side; it weighed 10½ pounds (4.7 Kg.).

Krogius [11] reported a case in which a lipoma weighing 6,150 Gm. was removed from a woman aged 51. The tumor was on the left side.

Pritzi [12] reported a case in a woman aged 62; the tumor was on the right side. Before operation there was a loss of function of the right kidney. After removal of the tumor, the renal function speedily returned to normal. There was a recurrence which originated from the left side and was so intimately attached to the kidney that the left kidney had to be removed. This demonstrated the desirability of having saved the right kidney at the first operation.

Mayo and Dixon [13] reported 3 cases. The first occurred in a woman, aged 45, who was operated on for an "ovarian tumor" and in whom at operation a 17½ pound (7.9 Kg.) retroperitoneal lipoma was found situated between the stomach and the colon. In the second case, there was an 18 pound (8.2 Kg.) fibromyxolipoma. The patient was operated on for a supposedly malignant condition. In the third case, the tumor was situated in the mesentery of the descending colon.

Burger [14] reported a case in a man, aged 61, in which a preoperative diagnosis of right-sided benign retroperitoneal tumor was made. The chief complaint in this case had been the occurrence of jaundice at irregular intervals. At operation it was found that the tumor involved the right flank, pushed the cecum to the midline and extended through the femoral ring. Burger thought that the tumor may have originated in the thigh and pushed upward through the inguinal ring.

Hunt and Simon [15] reported a case in a woman aged 49; the tumor was on the left side.

Katz [16] reported 2 cases. In the first case, there was a fibrolipoma on the right side, which recurred one and a half years later. In the

10. Johnson, P. P.: Retroperitoneal Perirenal Lipoma, Boston M. & S. J. **189**:907 (Dec. 6) 1923.

11. Krogius, A.: Research on So-Called Retroperitoneal Lipomas, Finska läk.-sällsk. handl. **67**:833 (Oct.) 1925.

12. Pritzi, Otto: Retroperitoneal Tumors, Arch. f. klin. Chir. **140**:583, 1926.

13. Mayo, C. H., and Dixon, C. F.: Retroperitoneal Lipoma: Report of Three Cases, Minnesota Med. **10**:272 (May) 1927.

14. Burger, T. O.: Large Retroperitoneal Tumor, S. Clin. North America **7**:1285 (Oct.) 1927.

15. Hunt, V. C., and Simon, H. E.: Perirenal and Intrarenal Lipoma, Am. J. Surg. **4**:390 (April) 1928.

16. Katz, N.: Ueber retroperitoneale Lipome, Beitr. z. klin. Chir. **142**:864, 1928.

second case, there was a liposarcoma on the left side, which weighed 18 pounds. The patient was operated on again two and five years later.

Crabtree [17] reported a case of pararenal lipoma with abdominal lipomatosis in a patient 60 years old. The preoperative diagnosis was retroperitoneal lipoma.

RÉSUMÉ

We have found many cases of retroperitoneal tumors reported in the literature, but have collected only those proved by excision and section to be lipomas or lipomas undergoing sarcomatous changes; in short, tumors of definite fatty origin. The recent cases do not bring out anything new or even materially change the statistics.

In summary, one might say that these tumors occur more frequently in women than in men, usually in the fourth or fifth decade. They arise most commonly from the perirenal fat. The most noteworthy feature is the absence of definite symptoms, as a rule, the chief complaint being the enlargement of the abdomen associated with vague abdominal discomfort. The symptoms are due entirely to pressure except in a few cases in which a loss of weight occurs apparently in surprising contrast to the enlargement of the abdomen.

The treatment is excision, which is sometimes easy and sometimes difficult. The chief difficulty usually lies in the freeing of the mesenteric vessels. Frequently one or another of the kidneys is so intimately engulfed in the mass that it must be removed. The desirability, however, of saving the kidney is demonstrated by Pritzi's case.[12]

There is a marked tendency for retroperitoneal lipomas to undergo sarcomatous change. Recurrences are not infrequent. Correct preoperative diagnosis is difficult, but in a few typical cases has been made. Roentgenograms are of great assistance in determining the origin of the tumor and renal tests in differentiating these tumors from polycystic kidney, hypernephroma or other renal tumors. Because of the possibility of having to remove the attached kidney at operation, renal function tests should always be made.

Our case demonstrates the feasibility of the transverse incision, which in this instance almost bisected the patient.

17. Crabtree, E. G.: Pararenal Lipoma with Generalized Abdominal Lipomatosis, Tr. Am. A. Genito-Urin. Surg. **22**:11, 1929; J. Urol. **23**:543 (May) 1930.

A RAPID METHOD OF PROTECTING THE PERITONEUM AGAINST PERITONITIS*

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The subject of peritonitis and especially its prevention by active immunity methods lately has aroused the interest of American investigators. The problem of active peritoneal immunity may be said to have been opened by Pfeiffer and Isaeff [1] with their demonstration of bacterial lysis within the peritoneal cavity in immunized animals (Pfeiffer phenomenon). This lysis was shown by the authors to be humoral and produced by the bacteriolysins of the serum. The next step was made by Piérallini,[2] who found that a leukocytic exudate could be obtained in the peritoneal cavity by the injection of foreign substances, including physiologic solution of sodium chloride. He was followed by Garnier,[3] who confirmed the presence of a leukocytic exudate in the peritoneal cavity of immunized animals, and found that bacteria are rapidly destroyed in the presence of such an exudate. Solieri [4] definitely applied such immune responses to peritonitis. He produced a peritoneal leukocytic exudate, and found that the animals with such a hyperleukocytosis survived a colon bacillus peritonitis. The subject was reopened in this country by Goldblatt and me [5] by the demonstration that intraperitoneal immunization by living and heat-killed colon bacilli induced an immu-

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* From the Laboratories and the Department of Medical Research of the Toledo Hospital.

* This work is a part of a general investigation on "Recovery in Peritonitis" aided in part by a grant by the Committee on Scientific Research of the American Medical Association.

1. Pfeiffer and Isaeff: Ztschr. f. Hyg. u. Infektionskr., 1894, vol. 17; Deutsche med. Wchnschr., 1894, no. 13.

2. Piérallini, G.: Sur la phagolyse dans la cavité peritonéale, Ann. Inst. Pasteur, 1897, p. 308.

3. Garnier, M.: Recherches sur la déstruction des microbes dans la cavité peritonéale des cabayes immunisés, Ann. Inst. Pasteur **11**:767, 1897.

4. Solieri, S.: Experimentelle Untersuchungen über die Veränderungen des Wiederstandes des Peritoneums gegen die Infection durch Bacterium coli, Beitr. z. path. Anat. u. z. allg. Path. **31**:536, 1902.

5. Steinberg, B., and Goldblatt, H.: Active Immunization Against Experimental Peritonitis, Am. J. Path. **3**:541, 1927.

nity to subsequent colon bacillus and fecal peritonitis. Later [6] we emphasized the preferable use of dogs as experimental animals and pointed out [7] that immunization with heat-killed colon bacilli was not as efficient as with living organisms. Herrmann [8] used rabbits as experimental animals and adopted our method of producing fecal peritonitis in those animals. He found that immunization with a mixture of colon bacilli and streptococci was more efficient than with colon bacilli alone. Although his protocols show only a difference of 5 per cent between the two methods in the survival of animals, he expressed the belief that because of the survival of some of the controls, the animals immunized with colon bacilli did not have as severe peritonitis as rabbits immunized with the mixture. Rankin and Bargen [9] applied clinically the process of active immunization, and expressed their belief that it protects the patient from peritonitis.

This work was undertaken to determine the shortest time in which active immunity could be conferred on an animal so that it could survive an experimentally produced peritonitis. The immunizing agents consisted of heat-killed colon bacilli and a mixture of the colon bacillus, streptococcus, Bacillus pyocyaneus, enterococcus, Bacillus mucosus-capsulatus and Bacillus welchii. These bacteria were isolated from appendixes with appendicitis and were of a determined marked virulence. Dogs were used exclusively as experimental animals.

EXPERIMENTS

EXPERIMENT 1.—*Immunizing Injections of Heat-Killed Colon Bacilli Followed by Production of Peritonitis with the Colon Bacillus.*—One group of twelve animals was given a single intraperitoneal injection of 1 agar slant of B. coli (300) consisting of 1,000,000,000 organisms. The slant was washed off with physiologic solution of sodium chloride heated at 60 C. for forty-five minutes, and injected intraperitoneally. On the following day each animal of the group, as well as four normal control dogs, received intraperitoneally 3 slants of living B. coli (300) suspended in 2.5 per cent tragacanth, U. S. P., made up in saline. All the controls died in from seven and one-half to sixteen hours of hemorrhagic fibrinopurulent peritonitis. Ten of the twelve dogs that had received a single immunizing dose of B. coli died of fibrinopurulent peritonitis.

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6. Goldblatt, H., and Steinberg, B.: Peritonitis: III. Active Immunization Against Experimental B. Coli Peritonitis, Arch. Int. Med. **41**:42 (Jan.) 1928.

7. Steinberg, B., and Goldblatt, H.: Peritonitis: IV. Production of Active Immunity Against the Fatal Outcome of Experimental Fecal Peritonitis, Arch. Int. Med. **42**:415 (Sept.) 1928.

8. Herrmann, Siegfried F.: Experimental Peritonitis and Peritoneal Immunity, Arch. Surg. **18**:2202 (May) 1929.

9. Rankin, F. W., and Bargen, J. A.: Vaccination Against Peritonitis in Surgery of the Colon, Arch. Surg. **22**:98 (Jan.) 1931.

Another group of ten animals was given two intraperitoneal injections of heat-killed B. coli. The first injection consisted of 1 slant (1,000,000,000); the second injection was given on the following day and consisted of 2 slants (2,000,000,000) of B. coli. On the day following the second injection, the ten animals and four normal control dogs were given B. coli and tragacanth to produce peritonitis, as were the first group. The four controls died. Eight of the ten dogs which had received the injections died.

A third group of ten dogs was given three intraperitoneal injections of heat-killed B. coli. The first injection consisted of 1,000,000,000 organisms; the second injection on the following day, of 2,000,000,000 organisms, and the third injection on the third day, of 3,000,000,000 organisms. On the day after the third injection,

TABLE 1.—*Immunization of Dogs with Varying Amounts of Heat-Killed Colon Bacilli and Followed by Production of Peritonitis with B. Coli at Varying Intervals Following the Immunization*

Number of Dogs	Number of Injections	Number of Days Between First Immunizing Injection and Peritonitis	Number of Dogs Survived	Number of Dogs Died
12	1	1	2	10
10	2	2	2	8
10	3	3	1	9
28	4	4	18	10

TABLE 2.—*Immunization of Dogs with Four Successive Injections of Heat-Killed Colon Bacilli and Followed by Production of Peritonitis with B. Coli at Varying Intervals Following Immunization*

Number of Dogs	Number of Immunizing Injections	Number of Days Between First Immunizing Injection and Peritonitis	Number of Dogs Survived	Number of Dogs Died
28	4	4	18	10
9	4	8	6	3
9	4	17	9	0
10	4	27	8	2

peritonitis was produced with B. coli and tragacanth in the group of ten animals and four normal control dogs. All the controls died; nine of the ten dogs which had received the injections died.

A fourth group of twenty-eight dogs (in series of 10, 10 and 8) was given four intraperitoneal injections of heat-killed B. coli. The first injection consisted of 1,000,000,000 organisms; the second injection on the following day, of 2,000,000,000; the third injection on the next day, of 3,000,000,000, and the fourth injection on the fourth day, of 4,000,000,000 organisms. Peritonitis was produced with B. coli and tragacanth in six normal control dogs and in the twenty-eight dogs the day after the fourth injection. All the control dogs died. Of the twenty-eight dogs, ten died.

A fifth group of twenty-eight dogs was given four intraperitoneal injections of heat-killed colon bacilli as the fourth group. In nine of these animals, peritonitis was produced with the colon bacillus eight days after the first immunizing injection;

six survived and three died. In another set of nine animals, peritonitis was produced with the colon bacillus seventeen days after the first immunizing dose. All of them survived. In the last set of ten dogs, peritonitis was produced with the colon bacillus twenty-seven days after the first injection. Eight survived; two died. With each set of animals, a similar type of peritonitis was produced in two normal controls. All the controls died.

EXPERIMENT 2.—*Immunizing Injections with a Bacterial Mixture Followed by Peritonitis Produced with the Colon Bacillus.*—One group of twelve animals was given four intraperitoneal injections of a heat-killed bacterial mixture previously described in a manner similar to that given the fourth and the fifth group

TABLE 3.—*Difference in Survival Following Immunization with Heat-Killed B. Coli and Immunization with Bacterial Mixture Followed by Peritonitis Produced with Colon Bacillus*

Number of Dogs	Number of Immunizing Injections	Number of Days Between First Immunizing Injection and Onset of Peritonitis	Type of Immunizing Material	Number of Dogs Survived	Number of Dogs Died
28	4	4	Heat-killed B. coli	18	10
12	4	4	Heat-killed bacterial mixture	3	9

TABLE 4.—*Difference in Efficacy of Immunization with Colon Bacillus and Immunization with a Bacterial Mixture in Relation to Survival Following Peritonitis Produced with Colon Bacillus*

Number of Dogs	Number of Immunizing Injections	Number of Days Between First Immunizing Injection and Peritonitis	Type of Immunizing Material	Number of Dogs Survived	Number of Dogs Died
10	4	27	Heat-killed B. coli	8	2
10	4	27	Heat-killed mixture	6	4

in experiment 1. Since there were six different organisms, each injection contained an equal sixth of each bacterium. Four days after the first immunizing dose, peritonitis was produced with the colon bacillus in each of the twelve animals and three normal control dogs. The three control dogs died. Of the twelve dogs, nine died and three survived. Table 3 shows the difference in survival between the animals immunized with the mixture and those immunized with the colon bacillus (experiment 1, group 4).

Another group of ten animals was given four intraperitoneal injections of a heat-killed bacterial mixture in the same manner as were the first group in the experiment. Twenty-seven days after the first immunizing dose, peritonitis was produced with the colon bacillus in the ten animals and in two normal control dogs. The control dogs died. Of the ten immunized animals, six survived and four died. Table 4 shows the difference in survival between animals immunized with the mixture and those immunized with colon bacillus (the final set of the

fifth group of experiment 1) after a period of twenty-seven days following the first immunizing injection.

EXPERIMENT 3.—*Immunizing Injections with Heat-Killed Colon Baccilli or with Bacterial Mixture Followed by a Peritonitis Produced by Injecting Intraperitoneally Three Slants of the Bacterial Mixture Suspended in Tragacanth.*—A group of ten animals was given four intraperitoneal injections of heat-killed colon bacilli as in the previous experiments. Another group of nine animals was given four intraperitoneal injections of a bacterial mixture. In the nineteen experimental animals and five normal control dogs, peritonitis was produced by injecting a bacterial mixture four days after the first immunizing dose. All of the control dogs died. Of the ten dogs immunized with colon bacilli, three survived and seven died. Of the nine dogs immunized with the mixture, two survived and seven died.

TABLE 5.—*Immunization of Dogs with Heat-Killed Colon Bacilli or a Mixture of Bacteria Followed by Production of Peritonitis with Bacterial Mixture Four Days After the First Immunizing Dose*

Number of Dogs	Number of Immunizing Injections	Kind of Immunizing Material Used	Number of Dogs Survived	Number of Dogs Died
10	4	Heat-killed B. coli	3	7
9	4	Heat-killed mixture of bacteria	2	7

TABLE 6.—*Difference in Percentage of Survivals of Animals Protected with Colon Bacillus and Animals Protected with Bacterial Mixture*

Percentage of Survivals	Method of Immunization	Type of Peritonitis Produced
65	Heat-killed colon bacilli	Colon bacillus
25	Heat-killed bacterial mixture	Colon bacillus
30	Heat-killed colon bacilli	Bacterial mixture
22	Heat-killed bacterial mixture	Bacterial mixture

COMMENT

From these experiments, it is apparent that some type of immunity is established by the intraperitoneal introduction of heat-killed bacteria. It is also apparent that the type of the colon bacillus (300) that I used (this organism has been used in all the previous experiments) is capable of establishing a higher degree of immunity than a mixture of virulent organisms most frequently found to be associated with appendicitis and peritonitis. A slight degree of protection is established following only one intraperitoneal injection when peritonitis is produced on the following day. The material used to produce peritonitis is from three to five times the lethal dose for a dog weighing from 10 to 15 Kg. If it were possible to grade the degree of peritonitis, it is very likely that even a greater percentage of survivals would have been obtained. The determination of agglutinins and the bactericidal power of the serum and of the peritoneal exudate following one, two, three and four peri-

toneal immunizing injections failed to reveal the presence of humoral antibodies (some of the dogs that were given four injections had an agglutinin titer of 1:100 or of 1:200) to account for this immunity. In a previous publication, Snyder and I [10] showed that an animal given time to establish immunity responds to peritonitis by a rapid and extensive polymorphonuclear mobilization and a rapid phagocytosis. The phagocytosis was found to be nonspecific; the polymorphonuclears

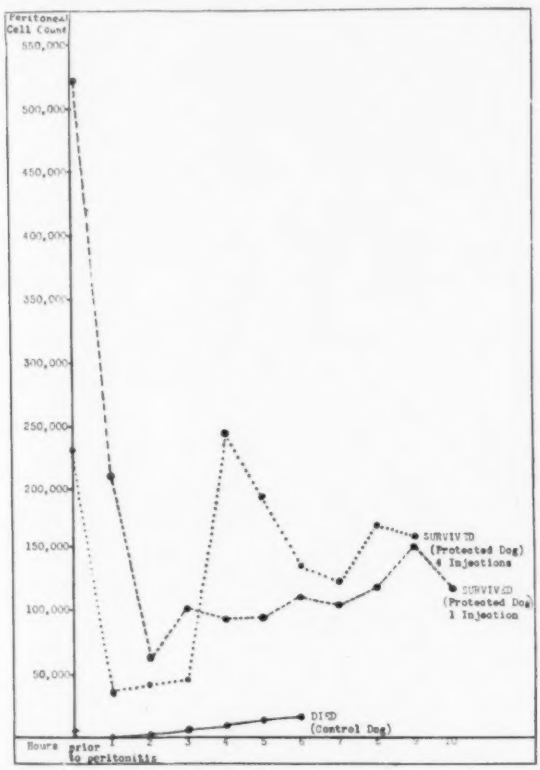

Chart 1.—Leukocyte counts per cubic millimeter of peritoneal exudate during the course of a colon bacillus peritonitis in a normal control dog, in an animal that had received one protecting bacterial injection and in another animal that had received four injections. Notice the marked difference in the cellular response between a normal and a protected dog.

evoked by immunization with colon bacillus phagocytosed indiscriminately all types of bacteria in the peritoneal exudate produced by fecal material.

Since humoral antibodies were not present, a study of the peritoneal exudate of the animals with a single, two, three and four immun-

10. Steinberg, B., and Snyder, D.: Immune Cellular Reactions in Experimental Acute Peritonitis, Arch. Path. **8**:419 (Sept.) 1929.

izing injections was made. The methods employed were those described by Snyder and me. Prior to the production of peritonitis, peritoneal and peripheral blood cell and differential counts were made. After the production of peritonitis, in addition to hourly peripheral and peritoneal cell counts, bacterial counts of the peritoneal exudate were made. The exudate was secured by puncturing, under sterile precautions, the abdominal wall with a capillary glass pipet.

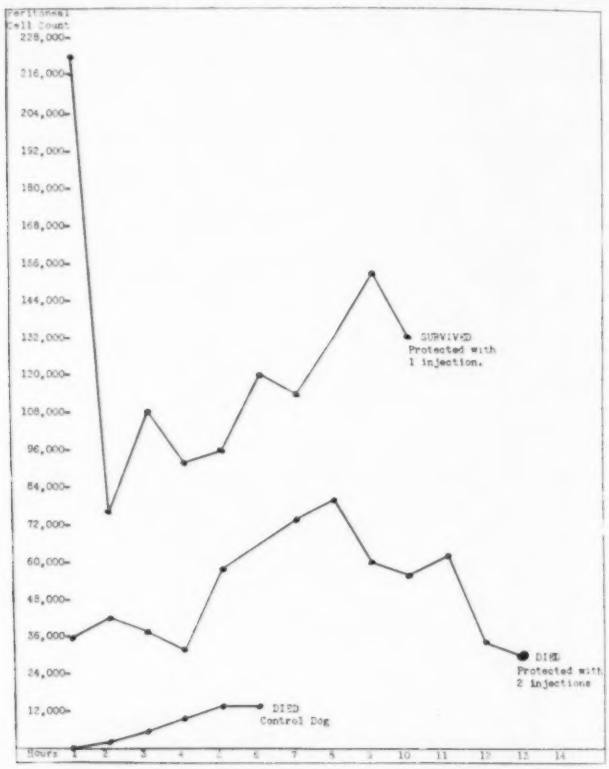

Chart 2.—Leukocyte counts per cubic millimeter of peritoneal exudate during the course of a colon bacillus peritonitis in a normal control dog, in a presumably protected animal that died and in a protected animal that survived. Observe the higher counts in the surviving animal, although it received one less protecting injection than the animal that succumbed.

Chart 1 shows the comparison of the peritoneal cell counts in cubic millimeters of exudate of a normal control dog with peritonitis, an animal given one and another animal four immunizing injections followed by the production of peritonitis with the colon bacillus. The animals with protecting injections have a decidedly greater number of cells in the peritoneal exudate. Chart 2 shows the difference between two ani-

mals; each had been given immunizing injections, but one died and the other survived following peritonitis produced by the colon bacillus. The surviving animal had a decidedly and consistently greater cellular peritoneal content than the animal that died, though the latter had

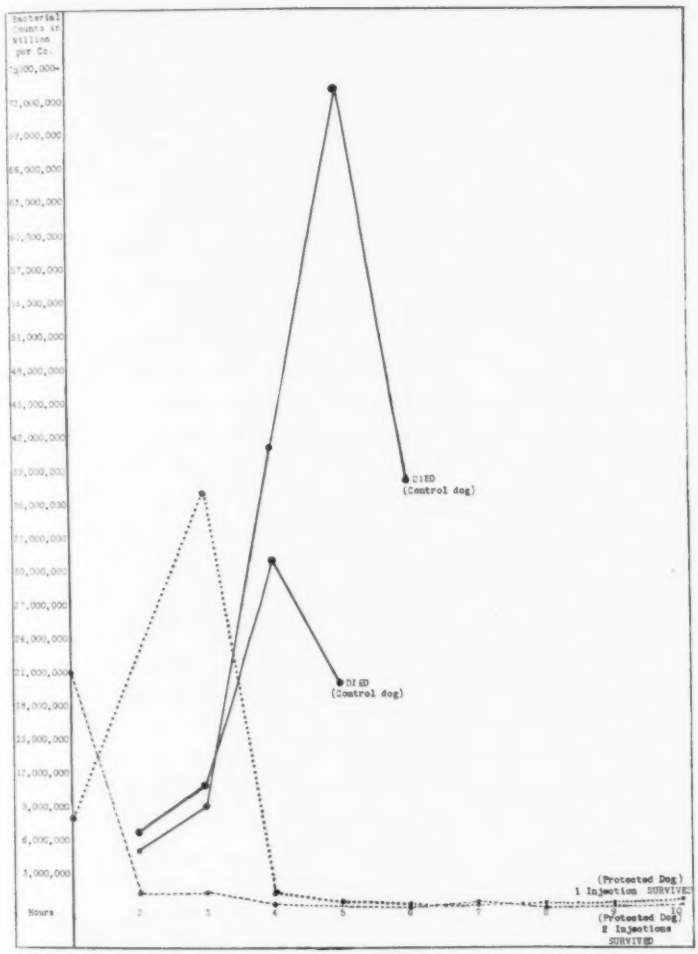

Chart 3.—Bacterial counts per cubic centimeter of peritoneal exudate during the course of a colon bacillus peritonitis in normal control dogs and in protected dogs. Observe the high bacterial counts in the normal dogs and the very low counts in protected dogs. Since the method of counting bacteria included the phagocytosed as well as the free bacteria, it is assumed that these counts represent the total number of all viable bacteria present in the peritoneal cavity.

received one more immunizing injection than the surviving animal. Chart 3 shows the difference in the bacterial counts of two normal control dogs and two animals that had received immunizing injections dur-

ing the course of a peritonitis due to the colon bacillus. It is apparent that in the normal control dogs the number of bacteria gradually rise during the first five hours and remain in large numbers until the animal dies. On the other hand, the dogs that received immunizing injections revealed a gradually diminishing number of bacteria. The contrast in the bacterial content of the normal control and the immune animals is striking.

Hourly examination of the peritoneal smears revealed complete phagocytosis in the protected animals within four hours, while smears from the normal control dog contained large numbers of bacteria throughout the course of the peritonitis. Since the bacteria are found phagocytosed within polymorphonuclears in the protected dogs and the bacteria show diminishing numbers, it may be assumed that either the bacteria are destroyed by the polymorphonuclears in situ or else the bacteria-laden polymorphonuclear cells migrate to other parts of the body. Three factors favor the conception of migration of leukocytes: 1. The ebb and rise of the cellular content in the peritoneal exudate (chart 2) suggest that the variation in number may be due to migration of old cells followed by a substitution by newly evoked cells. 2. The peritoneal smears do not reveal breaking up of bacterial bodies outside or within polymorphonuclears. 3. Bacteria are capable of surviving within a leukocyte for many days, as was demonstrated by Metchnikoff. The migration conception is further strengthened by experiments to be reported later in which the polymorphonuclears of immunized animals that died were traced from the peritoneal cavity.

It is apparent that in animals given a few immunizing injections and in which peritonitis is produced the following day the protecting mechanism cannot be considered either a humoral or a cellular immunity in the accepted sense. It may be said that the animals survive because phagocytes (polymorphonuclears) happen to be present in the particular locality in which the infection occurs. That the initial process is essentially and primarily that of phagocytosis is evident from these experiments. Such a process can hardly be classified as a local type of immunity, and I suggest the term "hyperleukocytic preimmunity".

APPLICATION OF THE PERITONEAL HYPERLEUKOCYTIC PRE-IMMUNITY TO MAN

Within the last two years, seventeen persons had been immunized by intraperitoneal injections of heat-killed colon bacilli prior to abdominal operations. These operations consisted of resection of the colon, intestinal anastomosis, old endometriosis with obstruction of the bowel and old appendical abscess. The immunizing material was given intraperi-

toneally daily on four successive days, and operation was done on the day following the last protecting dose. At present the protecting material consists of 50 cc. of physiologic solution of sodium chloride in which are suspended 4,000,000,000 colon bacilli (culture 300). The material is heated at 60 C. for forty-five minutes and made up to volume. After the determination of the absence of viable organisms the following doses are given: first day, 5 cc.; second day, 10 cc.; third day, 15 cc.; fourth day, 20 cc. The comparatively large amount of fluid allows the spread of the protecting material throughout the peritoneal cavity. At operation, the peritoneum shows a purulent peritonitis. The reactions experienced are slight and correspond to a mild peritonitis. All the patients made an uneventful recovery. Naturally, no conclusions regarding the merit of the procedure could be drawn from such a clinical application without properly controlled animal experimentation, which constitutes the only reliable criterion. At the present time, experiments are being undertaken to apply such peritoneal protection in acute and subacute pelvic inflammatory conditions.

SUMMARY

1. Protection against peritonitis can be obtained by the intraperitoneal injection of colon bacilli (culture 300).

2. Protection secured with heat-killed colon bacilli is greater than that obtained with a mixture of the virulent organisms usually found in appendicitis and peritonitis.

3. The protection secured is not a true immunity process, but a hyperleukocytosis and phagocytosis due to a coincident presence of polymorphonuclears at the site of infection. The term hyperleukocytic preimmunity is suggested for this process.

4. By means of these experiments on animals, a method is introduced that is applicable in the prevention of peritonitis in man following surgical intervention in the intestinal tract.

5. The protection can be achieved in four days, allowing the performance of the operation on the fourth or the fifth day after the first immunizing dose.

THE TREATMENT OF INTUSSUSCEPTION

REPORT OF A CASE WITH PERFORATION *

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The treatment for intussusception is primarily surgical. The surgical procedure involved is determined by the condition of the bowel as found at the time of the operation. Ordinarily, this condition depends on the time elapsing between the formation of the intussusception and the operation. Consequently, an early diagnosis becomes an important part of the treatment, since a relatively simple operation with the patient in good condition is usually the result.

DIAGNOSIS

There are two procedures of decided value in the diagnosis to which I wish to call attention. If an intussusception is suspected but not felt, either because of the abdominal distention or because of the child's crying, the following procedure will often result in a positive diagnosis. The examiner's right index finger is placed in the child's rectum and his left hand on the abdomen. The assistant then holds the child in a sitting posture with its face toward the examiner. The tumor will usually drop down between the examiner's hands.

When the diagnosis is not certain, or if it is made and the position of the lesion not located, roentgen examination is advisable. When the condition of the patient calls for as little loss of time as possible, a roentgenogram of the abdomen made without any preparation will often show the distended loops above the lesion and indicate the position of the intussusception by the difference in the shadow of the large and small intestine.

Le Wald [1] has demonstrated graphically the value of the barium enema in the diagnosis of intussusception when the patient's condition permits. If the obstruction is complete, the site will be shown. If it is incomplete, the enema will show the constriction and may show where the barium filters around the invagination and remains after the enema has been expelled from the bowel.

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* Submitted for publication, May 19, 1931.

* From the surgical service of St. Luke's Hospital.

1. Le Wald, L. T.: Johnson's Operative Therapeusis, New York, D. Appleton and Company, 1915, vol. 4, chapt. 3, p. 208; personal communications.

REDUCTION

Nonoperative Reduction.—The reduction of an intussusception may be nonsurgical, accomplished by the use of pressure enemas or air insufflation; but if this method is successful, it should be followed by abdominal exploration to make certain that reduction is complete and that there is no gangrene, perforation or tumor present. Both Farr [2] and Montgomery [3] recommend the aid of air insufflation of the colon in the reduction of all intussusceptions at the time of operation. This simplifies the locating of the lesion, reduces the less severe ones without handling of the intestine other than for exploration and makes possible reduction in some of the advanced cases in which the intussusception otherwise might not be reducible. The procedure should at all times be under visible control. The air empties readily from the rectum.

Operative Reduction.—A small, early intussusception is easily reduced, and the operative procedure is completed. Also many of the larger, later and consequently more edematous intussusceptions may be reduced. Careful manipulation is necessary, as the tissues are very friable. Gentle stripping, rolling or milking back of the intussuscipiens while constant but gentle backward pressure is maintained on the apex of the intussusceptum will usually bring about reduction. McGlannan [4] stated that a flat blunt dissector or the handle of the knife introduced inside of the neck may aid the reduction. If the intussusception is wrapped in moist gauze, and even, steady pressure applied for a few minutes, with great care, the edema may be so relieved that reduction becomes possible.

The intestines should at all times be protected with gauze saturated with warm physiologic solution of sodium chloride, and they should be kept within the abdominal cavity as much as the operative procedures will permit. Cheever [5] advises that, if greatly distended, the intestine be eviscerated into a moist rubber dam bag kept warm by hot compresses to its exterior surface, provided that the distended loops prevent the necessary exploration or operative procedures.

TYPES OF INTUSSUSCEPTION

Irreducible Intussusception.—Some cases will be found in which reduction cannot be accomplished. Formerly, it was the practice of

2. Farr, C. E.: The Reduction of Colonic Intussusception by Air Inflation, Ann. Surg. **84**:588 (Oct.) 1926.

3. Montgomery, A. H.: Intussusception and Some other Surgical Conditions of the Abdomen in Children, Nebraska M. J. **15**:21 (Jan.) 1930.

4. McGlannan, Alexius, in Lewis: Practice of Surgery, Hagerstown, Md., W. F. Prior Company, 1929, vol. 7, chapt. 4, p. 22.

5. Cheever, David, quoted by Hartwell and Cooper, in Lewis: Practice of Surgery, Hagerstown, Md., W. F. Prior Company, 1929, vol. 7, chapt. 7, p. 33.

many surgeons in this type of case to incise the bowel at the point of invagination, reduce the intussusception and close the opening thus made. A simple and effective method for making the incision is described by Brown.[6] One blade of the scissors is inserted under the edge of the neck of the intussusception, and the neck is cut across parallel to the long axis of the intestine.

For irreducible intussusception in children, not complicated by gangrene, McGlannan [4] advises enterostomy above the lesion when one-stage resection is contraindicated by the patient's condition. He stated that this may be followed by spontaneous reduction, and feels that multiple stage resections in children do not give good results. Of course, should reduction not occur following the first operation, a second operation for the purpose of reducing or resecting the intussusception would be necessary.

Others drop the intussusception back into the abdomen and do a lateral anastomosis between the afferent and efferent loops of intestine; for example, in an intussusception at the ileocecal valve, an anastomosis is made between the terminal ileum and the ascending or transverse colon. To this procedure Montgomery [7] has added a fixation of the invagination by placing a few interrupted sutures through the serosa and muscularis of the two portions of the intussusception at its point of entrance. This prevents leakage as the invaginated portion sloughs off.

Gangrenous Intussusception.—At times the pressure on the invaginated blood vessels has been great enough and has existed sufficiently long for the intestinal wall to become gangrenous. If this condition is diagnosed before reduction is accomplished, the logical treatment would be by one of the methods just described. But, when the condition is found after reduction, removed of the involved portion is indicated.

A resection followed by a lateral anastomosis is the ideal operation. In most cases the condition of the patient, usually an infant, will not justify the time necessary for the operation and the manipulation involved. A "double-barrel" resection is a life-saving procedure under such circumstances. The involved loop is brought out through a second incision, but if the patient's condition is critical, the loop may be brought out through the original incision. A few sutures will hold the "barrels" together. A drain is placed in the peritoneal cavity, and the wounds are closed.

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6. Brown, H. P., Jr.: Acute Intussusception in Children, Ann. Surg. **81**:637, 1925.

7. Montgomery, A. H., and Mussil, J. J.: The Treatment of Irreducible Intussusception in Children, Surg., Gynec. & Obst. **51**:415 (Sept.) 1930.

An "extra-abdominal" ileostomy is then done in the following manner.

A number 16 soft rubber catheter is inserted into the proximal end of the intestine just distal to its emergence from the incision and held in place with a purse-string suture. The catheter should extend several inches into the intestine. The loop is clamped off with one or two large clamps, and cut away at once with the cautery. The clamps are left on until there is necrosis of the end of the intestine and leakage occurs. This is usually on the fourth or fifth day. In the meantime, the wound is protected and the obstruction is relieved by the catheter. When healing occurs, a clamp is put on with a jaw in each end of the intestine, and by pressure necrosis the lumina of the two ends are joined This should be done as deeply as possible to insure a large connection. Later a closure is done by the intraperitoneal or the extraperitoneal method, whichever is indicated.

Perforation.—To the gangrenous intussusception may be added the complication of perforation. When gangrene does develop, it is ordinarily in the portion of the intussusception that is within the intestinal lumen, so that perforation does not necessarily soil the peritoneal cavity. However, by pressure closing the vessels to the wall of the intussuscipiens or by direct pressure of the intussusception against the intussuscipiens, a small area of necrosis with resulting perforation into the peritoneal cavity may result. This is the condition that was found in the case reported in this paper.

The ideal treatment would be closure of the small perforation by two purse-string sutures, or, if the intestine is gangrenous, resection and lateral anastomosis with drainage of the peritoneal cavity. But in these cases, even more so than in any of the types already considered, a brief operation with the least possible trauma is indicated. As perforations are not to be expected in the cases that are readily reduced and show no other damage to the intestinal wall, the treatment in such cases need not be considered here.

Once more, the quickest procedure that will remove the damaged intestine, relieve the obstruction and care for the soiled peritoneum is the modified Mikulicz operation, which has just been described. Time will be saved by bringing the loop out through the original incision. Adequate drainage should be established by the insertion of rubber dam drains.

ADDITIONAL TREATMENT

The procedure in all operations for intussusception must include a careful palpation for a tumor in the intestine as a possible cause for the condition. Such tumors have been reported as multiple in some cases, even causing a later second intussusception. If found, the tumor should be removed by whatever type of operation its nature and the patient's condition dictate.

As to an anesthetic, ether will usually be found best suited to the needs. The required manipulations are very difficult to do on an infant, or even on a child, under local anesthesia.

Preoperative preparation should include the administration of water, salt and dextrose by hypodermoclysis or infusion. If indicated, the stomach should be lavaged. A patient in poor condition may be carried through the operation by a preoperative blood transfusion.

Immediate postoperative treatment for shock by intravenous injection of a saline solution, by blood transfusion or by both is often indicated, and will save many patients. Later, attention should be given to the maintenance of the fluid and salt balance and of nutrition, as indicated by the continuation of these measures plus hypodermoclysis.

When an enterostomy has been done, the catheter is irrigated with physiologic solution of sodium chloride or sodium bicarbonate solution every one or two hours and allowed to drain the remainder of the time. This prevents stoppage and possibly adds to the patient's fluid intake.

If resection has been done by the Mikulicz method, the skin about the wound is protected for the first four or five days by leaving the clamps in place and allowing drainage to take place through the catheter. When the clamps no longer hold, the skin is protected by the use of a paste made of kaolin and glycerin or by the use of tenth-normal hydrochloric acid and 10 per cent peptone solution. These solutions are introduced at half-hour or hourly intervals through a perforated tube incorporated in the dressing and encircling the ends of the intestine. Whatever excoriation does occur will be found to clear up rapidly as soon as the lumina of the ends of the intestine are united.

If the patient is an infant, particular emphasis should be placed on every possible effort being made toward getting the child out of the hospital at the earliest possible moment. The reason for this is self-evident when the effect of hospitalization on the normal infant is seen.

There is one more point to be noted in passing, which is an old story to the surgeon who has had a large number of these cases. An appendix delivered from an intussusception is so distended by the passive congestion that at first glance it may look as though the patient had acute appendicitis. It is very unwise to add an unnecessary appendectomy to a situation already precarious.

REPORT OF A CASE

History.—T. T., a boy, aged 15 months, was first seen in the pediatric dispensary at St. Luke's Hospital, on Oct. 8, 1930. Two days before, he had had diarrhea—foul mucus stools—with nausea and frequent vomiting. There had been some blood in an enema return, which the mother thought due to trauma.

The child was put on a regimen of forced fluids and sent home. On October 10 he was brought back to the clinic for reexamination. He had continued to vomit, and his abdomen was moderately distended. There had been no bowel movement,

but an enema had returned brown flakes and mucus with some flatus. As he appeared sick, although he had no fever and his blood count was normal, he was admitted to the hospital to the pediatric service.

October 11: The child continued to vomit, but did not look very sick. An enema returned a small amount of brown material and mucus. At one time when he was quiet, an indefinite mass was felt under the edge of the liver.

October 12: The child appeared sicker. The leukocyte count had doubled, being 12,200, with polymorphonuclears, 60 per cent, and lymphocytes, 40 per cent. Tenderness and rigidity had developed in the right side of the abdomen. Enemas gave no results except flatus in small amounts.

A surgical consultation was then asked for. When a rectal examination was made with the patient held in the sitting position, a mass dropped down between the examining fingers and the examiner's other hand.

Operation was done at once, with a diagnosis of chronic intussusception, which had developed acute signs in the right side of the abdomen.

Pathologic Findings.—The peritoneal cavity contained a considerable amount of serosanguineous fluid. The entire small intestine was greatly distended. At the ileocecal junction there was an intussusception forming a sausage-shaped mass nearly 6 inches (15.24 cm.) in length. This was located well up under the edge of the liver.

The right lumbar gutter contained fecal material and thin seropurulent fluid. In the cecum were two perforations the size of a finger-tip. The invaginated ileum was gangrenous, and on the adjacent loops of intestine there was a considerable deposit of fibrin.

Operative Procedure.—Under ether anesthesia, a rectus incision was made to the right of the umbilicus. The intussusception was located with considerable difficulty, but could be delivered into the incision. The terminal ileum proximal to the gangrenous intestine and the ascending colon distal to the perforations in the cecum were approximated with four interrupted chromic catgut sutures. A through-and-through suture was placed at each end of the incision; a small soft rubber dam drain was placed on each side of the loop of intestine, the upper into the right lumbar gutter and the lower into the pelvis. The loop of intestine was clamped and cut away with the cautery. This loop included the cecum, the appendix and the terminal 10 inches (25.4 cm.) of ileum. A number 16 soft rubber catheter was placed in the protruding end of the ileum and held in place with a purse-string suture. Foul brown fluid ran from the tube as soon as it was introduced.

Postoperative Course.—Immediately after operation, an infusion of 400 cc. was given, followed by a transfusion of 200 cc. of whole blood from the mother. Following this, the child's condition was fair.

Hypodermoclysis of 300 cc. of saline solution was given every eight hours until the end of the second day. It was then given only twice daily, as the child took fluids freely without nausea. The catheter was irrigated with physiologic solution of sodium chloride every hour.

The child's temperature remained between 104 and 105 F., and on the third postoperative day, he was given another transfusion of 200 cc. of whole blood from the mother to maintain nutrition.

Beginning on the fourth day the temperature declined, and by the sixth day was normal.

The clamps came away on the fourth day, and on the eighth day a Mikulicz clamp was applied to the two ends of the intestine. The next day the child's

temperature was 104 F. He looked sicker, and another transfusion of 200 cc. of whole blood was given.

His general condition improved gradually, the temperature dropped to normal, and on the eleventh day fecal material was passed by rectum. On the twelfth day, the clamp had cut entirely through.

As the opening between the two loops appeared to be too small, the Mikulicz clamp was reapplied, but gave a very inadequate opening. Consequently, two Kocher clamps were applied. This was an unfortunate measure, as the lateral clamp caused a perforation of the intestine that night. Stab wound drainage was instituted in the right flank, and in two days the temperature had returned from 105 F. to normal.

Convalescence continued uneventfully from that time. The drainage wound closed, the opening into the intestine became smaller gradually, and the child passed a normally formed stool every day. His strength and general condition improved steadily.

At the end of the tenth week he began to cough, and a white blood count of 129,000 developed, with polymorphonuclear leukocytes, 28 per cent, and lymphocytes, 72 per cent. By the next day this proved to be a definite and very severe case of whooping cough. Notwithstanding intensive treatment with vaccine and deep roentgen therapy, the child died one week after the onset of the disease.

SUMMARY

A detailed outline of the treatment for intussusception, particularly of the more severe types, is given.

A case of intussusception is reported which occurred in a child 15 months of age. In this case the intussusception had perforated, was irreducible and gangrenous. It was treated by a modified Mikulicz resection, with drainage of the peritoneal cavity. The child was apparently well on the road to permanent recovery when, in the eleventh postoperative week, he contracted whooping cough, from which he died three months after the original operation.

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FORTY-SIXTH REPORT OF PROGRESS IN ORTHOPEDIC SURGERY

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(*Concluded from p. 170*)

SYMPATHETIC NERVOUS SYSTEM

Sympathetic Ramisection.—Royle [26] made a study of the results obtained by the operation of sympathetic ramisection, basing his conclusions on a questionnaire sent to each of his patients, to which he received 126 replies, and on his records of the remainder of the 600 patients on whom he had performed the operation. There were three deaths, giving a mortality rate of 0.5 per cent. He tabulated the results according to the patients' answers as follows:

Congenital spastic paraplegia. Some benefit was obtained in 88 per cent of all patients, and good or excellent results in 75.6 per cent.

Congenital spastic hemiplegia. Some benefit was obtained in 97 per cent, and excellent or good results in 71.4 per cent.

Congenital spastic chorea. Some benefit was obtained in 100 per cent, and excellent or good results in 70 per cent.

Acquired spastic hemiplegia. Some benefit was obtained in 94 per cent, and excellent or good results in 58 per cent. Since a more complete

26. Royle, N. D.: Canad. M. A. J. **24**:229, 1931.

operation had been employed, including a thoracic sympathetic resection, the results were better.

Acquired spastic paraplegia, including disseminated or lateral sclerosis. Excellent or good results were obtained in all cases, but the numbers were too small to be reliable.

Parkinsonian rigidity. Some benefit was obtained in 68 per cent, and excellent results in 27 per cent.

Chronic constipation and megacolon. Excellent or good results were obtained in 100 per cent in each class of disease.

Raynaud's and Buerger's disease. Excellent or good results were obtained in 100 per cent of the patients with Raynaud's disease, and in 66 per cent with Buerger's disease.

Other conditions in which the operation had been performed were writer's cramp, sarcoma of the femur (for pain), anterior poliomyelitis, conditions simulating tic douloureux, unusual vasospactic conditions and retinitis pigmentosa.

The reports of other observers, however, have been less favorable as to the results of sympathetic ramisection. Thus Herz [27] studied the end-results in thirty-six patients, of whom thirty-two had been operated on by Royle himself. In nineteen cases the operation had been performed because of Little's disease. Of particular importance in evaluating the results were those patients in whom the operation had been done on one side only. Herz considered that the results in all cases were nil.

[ED. NOTE.—A vast amount of study, both experimental and clinical, has been devoted to the sympathetic nervous system in the last few years, and the physiologic effects of excision of parts of the sympathetic nerve chain in the different regions have been measured. The evidence has tended to show that the chief effects are an improvement in the circulation of an extremity due to vascular dilatation. It is probable that whatever improvement has been obtained by the operation in spastic paralytic conditions, and many observers dispute the claim of any improvement, has resulted from the increased blood supply.]

MISCELLANEOUS

Effects of Physical Therapy on Function and Structure.—Wolfson [28] summarized the results of studies made in the laboratories of Northwestern University Medical School of the effects of physical therapeutic procedures on the blood flow of a normal limb. Heat produced

27. Herz, M.: Zentralbl. f. Chir. **57**:78, 1930.

28. Wolfson, H.: Studies on Effect of Physical Therapeutic Procedures on Function and Structure: Effect of Blood Flow in Normal Limb, J. A. M. A. **96**: 2019 (June 13) 1931.

an increased blood supply due to active dilatation of the blood vessels. Massage and passive motion by mechanically emptying the blood vessels caused a temporary increase in the rate flow. Electricity, as applied, was effective in increasing the blood flow; its value in the treatment for poliomyelitis and peripheral nerve injuries might be due to some other effects not studied in these experiments. The suggestion was made to use more frequent but shorter treatments of massage and passive motion.

Volkmann's Ischemic Contracture in Hemophilia.—An interesting case of Volkmann's contracture developing following a hemorrhage in the arm in a patient with hemophilia, aged 8 years, was reported by Pasquali.[29] No bandage or splint had been used. He pointed out the medicolegal significance of the case as proving that ischemic contracture might develop in the entire absence of any external dressing.

Traumatic Lipo-Arthritis of Knee.—Under the name of lipoarthritis, Diamant-Berger and Sicard [30] studied the reactions provoked by trauma in the periarticular fatty tissues of the knee. From a review of the literature and after anatomic and physiologic investigations, they divided the physiopathologic manifestations into three types: one in which the lesion was localized to the infrapatellar fat pad (Hoffa's disease); a second in which the lesion was confined to a synovial fringe or solitary lipoma, the extracapsular lipoma of Lancereaux, and a third type that was generalized corresponding to the lipoma arborescens or the intracapsular lipoma of Lancereaux.

Hoffa's disease was always of traumatic origin, although this might be a single severe injury or several slight injuries. One found the infrapatellar fat pad hyperplastic and of a fibrous consistency, and on microscopic examination there was evidence of a subacute inflammatory reaction. The patient complained of pain localized to the anterior and medial part of the joint, aggravated by walking and worse at the moment of complete extension of the knee. These symptoms were sometimes accompanied by sensations of pinching in the joint, although less distinct than the locking caused by a loose body. Examination disclosed peripatellar swelling, readily palpable and giving the impression of fluctuation. Motions of the knee were free and painless except on extreme extension.

In the second type of lesion or solitary lipoma a history of an initial trauma was usually obtained. At arthrotomy one found a mass, either single or lobulated, attached by a pedicle of greater or lesser length, situated in one of the parapatellar culdesacs. The symptoms

29. Pasquali, E.: Chir. d. org. di movimento **15**:465, 1931.

30. Diamant-Berger, L., and Sicard, A.: Rev. d'orthop. **18**:5, 1931.

were those of a chronic posttraumatic synovitis with a localized area of pain, and accompanied by sudden sharp aggravations of pain and symptoms of locking. Synovial effusion commonly accompanied this lesion, whereas it was usually absent in the previous type. The authors called attention to the fact that these lipomas might develop torsion of their pedicles, and reported a typical instance.

The history of trauma in the third or generalized form was less clear, and sometimes it seemed to develop spontaneously. The finding at arthrotomy was a marked villus arthritis. The symptoms were those of a chronic hydro-arthrosis, resistant to treatment and tending to recur.

The treatment varied according to the type of the lesion. In the localized infrapatellar fat pad lesion it was always worth while to try conservative measures in the beginning. The only operative treatment was total extirpation of the infrapatellar fat pad through a unilateral or bilateral parapatellar incision. In the solitary lipoma type of lesion operative removal ought to be advised. On the other hand, in the generalized form the advisability of operation was to be debated. One ought to try conservative treatment first, and it was only in case of complete failure that one would advise synovectomy.

Pellegrini-Stieda's Disease.—A very comprehensive discussion of the common metatraumatic ossification revealed by roentgen examination in relation to the internal femoral condyle of the knee was published by R. Petrignani.[31] Usually associated with the name of Stieda, the author found it more exact to employ the name of its real discoverer, Pellegrini, whose publication preceded that of Stieda by two years. The bony formation was always of traumatic origin. It was found more frequently in men between the ages of 25 and 40 years and in laboring men or those engaged in athletics. The traumatism might be a direct contusion, indirect as a result of muscular contraction, or sprain, or a mixture of both sprain and contusion. In certain of the cases there was produced a fracture of the epicondyle, in others an avulsion of a small fragment of bone, and this was followed by ossification. In still others, and probably this was the more common mechanism, ossification developed in the fibrous covering of the epicondyle by a process of metaplasia after absorption of the hematoma produced by the trauma.

The symptoms associated with the lesion were variable, slight pain at the moment of injury being the chief sign, followed sometimes by functional weakness of varying severity. Swelling and heat were sometimes found on examination. Frequently there were no symptoms, and the patient sought advice only because the presence of a swelling had been noted. The presence of a bony nodule in the region of the epicondyle

31. Petrignani, R.: Rev. d'orthop. **18**:105, 1931.

was the chief sign; sometimes it was tender and at others not. Patients who had been injured when at work often complained of more serious functional disturbances, but it was necessary to be on one's guard in accepting these. As far as the diagnosis was concerned, it depended chiefly on the roentgen examination.

The evolution of the bony nodule was variable; occasionally it completely disappeared in the course of time; more often it enlarged to a certain degree, then reached a degree of stability where it no longer changed and was relatively inert, and very rarely it might evolve into a large mass and cause considerable disturbance. Only rarely was surgical removal necessary, and this was indicated only when the ossification had reached a state of maturity and was voluminous in size, bothersome and painful.

Osteochondritis Dissecans.—Böhler [32] denied that osteochondritis dissecans was of traumatic origin. In a large experience with traumatic bony injuries he had observed many intra-articular fractures with separation of bone fragments of various sizes, but had never seen any that resulted in an appearance similar to that seen in osteochondritis dissecans. He was inclined to feel that this lesion had its origin in endocrine dysfunction, perhaps stimulated or resulting from environmental conditions.

Roentgen Evidence of Lead Poisoning.—Park and his co-workers [33] reported four cases of chronic lead poisoning in children with shadows at the ends of the growing bones similar to those described after continued administration of phosphorus. The authors believed that these shadows occurred only when lead had been taken sufficiently long and in sufficiently large dosage. The changes were best observed in the more rapidly growing parts of the skeleton, and were most marked in very young children. Two of the cases came to autopsy. In the long bones the trabeculae were found to be far more numerous than in normal bones at the zone of provisional calcification. The shadows were due either to this modification of the trabeculae or to actual deposition of lead here, or both.

[ED. NOTE.—Although the orthopedic surgeon is not likely to be called on to diagnose or treat lead poisoning in children, it is important for him to know the possible causes of abnormal appearance of the bone as revealed by roentgenograms, and the work of Park and his co-workers ought to interest him from this standpoint.]

32. Böhler, L.: München. med. Wchnschr. **77**:109, 1930.

33. Park, E. A.; Jackson, D., and Kajdi, L.: Shadows Produced by Lead in X-Ray Pictures of Growing Skeleton, Am. J. Dis. Child. **41**:485 (March) 1931.

SURGERY OF BONES, JOINTS AND TENDONS

Treatment for Paralytic Deformities by the American and German Schools of Orthopedic Surgery.—Reviewing the various orthopedic procedures employed in the treatment for paralytic deformities by the American and German schools, Lange [34] pointed out that there was no essential difference of opinion in respect to paralyses of the knee and arm. In both countries paralyses of the knee were treated either by tendon transplantation or braces, or both, rather than by arthrodeses. In the case of the arm, arthrodesing operations were done at the shoulder or wrist only when there were no muscles sufficiently strong to be worth transplanting. Paralytic scoliosis was usually treated in Germany by supporting braces and exercises, while the operation of spinal fusion was often resorted to in America. In hip paralyses the German orthopedic surgeons preferred muscle transplantation, while in the United States such operations were not frequently performed. Bone and joint operations were for the most part not done before the fourteenth year in German clinics. Before this age deformities were prevented or corrected by exercises, manipulations and tendon transplantations. After the fifteenth year, both the American and German schools were in accord that paralytic deformities of the feet should be corrected by operations chiefly attacking and fusing the subastragalar joint while preserving as much motion as possible at the ankle joint.

The Arthroscope.—A preliminary report of a method of direct visual examination of a joint with the opportunity for the removal of specimens of tissue by means of an arthroscope was made by Mayer and Finkelstein.[35] Special instruments had been devised to be employed in conjunction with the arthroscope. Three case histories were reported in which the method had been used. The authors stated that though the value of the method was at the present time problematic, their experience had encouraged them in the belief that the instrument would enable more accurate diagnosis of joint lesions than any method previously devised.

[ED. NOTE.—The idea of arthroscopy is not new, and previous investigations along this line have been made by other authors. Mayer and Finkelstein seem to have refined the apparatus and the technic. The weakness of arthroscopy lies in the fact that it is itself an operation and may involve greater risk while yielding less information and less opportunity for treatment than an exploratory operation.]

34. Lange, F.: J. Bone & Joint Surg. **13**:479, 1931.

35. Mayer, L., and Finkelstein, H.: J. Bone & Joint Surg. **13**:583, 1931.

Lacerated Wounds Involving Tendons.—Böhler [36] warned the general practitioner against undertaking the difficult task of suturing injured tendons, and advised him to confine his attentions only to providing first aid care of the wound, and to send the patient as quickly as possible to a hospital where suitable facilities for thorough treatment were available. When immediate hospitalization was not possible because of distance or other causes, the best thing to do was to clean the wound and close it, but without suture of the injured tendon. Even in hospitals only smoothly severed tendons should be sutured primarily; other cases with lacerations of the tendons, extensive trauma of the soft tissues or injuries of the bones should be reserved for secondary suture. But even this ought not to be attempted when the structure damaged was the flexor tendon of the finger at the level of the proximal phalanx on account of the uniformly bad results obtained by any type of suture.

[Ed. Note.—Even admitting that the results of suture of the flexor tendons of the fingers are uniformly bad, there are still enough exceptions to this rule to justify trial of the method in selected cases. The only other alternatives are late tendon transplantation, a procedure that is often unsuccessful, or amputation. A stiff finger is always a great handicap to an otherwise normally functioning hand.]

Arthrodesis of the Hip.—A method was described by Abbott and Fischer [37] for securing ankylosis of the hip in cases of tuberculous arthritis in which the head and neck of the femur had been completely destroyed and the acetabulum markedly eroded. The procedure had been carried out in several stages; first, the correction of deformity; second, arthrodesis of the hip by denudation of the bony surfaces with fixation of the hip in wide abduction almost at a right angle to the axis of the body, and third, reduction of the widely abducted position of the hip after ankylosis had been obtained by subtrochanteric osteotomy.

The authors reported the cases of eleven patients, all with advanced destruction of the hip, in whom the method had been employed and in whom highly satisfactory results had been obtained except in the case of two patients who had discharging sinuses. In one of the latter an incomplete ankylosis and a discharging sinus still remained at the end of eleven months, while in the other case clinical ankylosis with healed sinuses was present after fourteen months. All of the others were able to walk and sit in comfort without pain. In seven cases the average time before roentgen evidence of beginning ankylosis was obtained was four and one-half months. The average length of time

36. Böhler, L.: Med. Welt **4**:1030, 1930.

37. Abbott, L. C., and Fischer, F. J.: Surg., Gynec. & Obst. **52**:863, 1931.

elapsing between the arthrodesis and the correction of wide abduction by osteotomy was five and nine-tenth months.

[ED. NOTE.—No definite conclusion in respect to the value of the procedure described by Abbott and Fischer can be drawn before more extensive trial has been made of it by other surgeons. It is to be noted, however, that it is intended to be used only in that group of cases in which there has been extensive bony destruction or dislocation, the type that is most difficult to fuse by ordinary methods. We feel that the stability of the hip together with the close approximation of the bony surfaces obtained by the position of extreme abduction ought to conduce toward obtaining ankylosis. If this can be obtained with certainty in a high percentage of cases the disadvantage of a subsequent osteotomy ought to be regarded in comparison as of only slight importance.]

Transplantation of the Biceps Femoris Muscle for Quadriceps Paralysis.—Crego and Fischer [38] studied the end-results in sixty-one patients in whom the biceps femoris muscle had been transplanted for paralysis of the quadriceps femoris muscle. The ages at which the operation had been done ranged from 5 to 22 years. Of sixty patients with satisfactory results, only three had power in the quadriceps at the time of operation. In six patients there had occurred a varying degree of return of power in the quadriceps. One case was a failure due to lack of cooperation in the after-treatment. The authors stated that the operation was contraindicated in the presence of deformity of the knee or hip, in the absence of sufficient posterior support of the knee and where there was no possibility of discarding mechanical support. In the operation itself it was necessary to prepare an adequate patellar bed for the transplanted tendon; also to free the biceps femoris upward sufficiently to secure the maximum oblique pull, and also to suture the biceps tendon firmly to its new insertion under tension with the knee fully extended. To insure a good functional result exercises and massage had to be begun in the third or fourth week, and mechanical support for the knee ought to be worn for a year. Exercise treatment of the knee ought to be continued from twelve to eighteen months. The common complication was genu recurvatum. It was best treated by prolonged mechanical support of the knee, holding it in slight flexion.

FRACTURES

The Breaking Strength of Healing Fractures.—The breaking strength of a healing fracture was studied by Howes and Lindsay [39] in the fibula of the rat. A standardized type of experimental fracture was

38. Crego, C. H., and Fischer, F. J.: J. Bone & Joint Surg. **13**:515, 1931.

39. Howes, E. L., and Lindsay, M. G.: J. Bone & Joint Surg. **13**:491, 1931.

produced by cutting the fibula with a scissors in each of 250 rats. The animals were killed in groups of five at three day intervals, and the specimens recovered. Each of the specimens was subjected to tests in a machine which accurately measured the resistance of the newly formed callus to tensile strain.

The authors found no resistance at the fracture site before the sixth day, but that after this the strength of the callus increased rapidly to the twenty-first day. It then diminished to the thirtieth day, when it rose again to a permanently high level. The authors felt these findings agreed with the clinical and histologic observations on healing fractures. The first period up to the sixth day corresponded to the preliminary process of fibrosis. The second period up to the twenty-first day corresponded to the period of increasing size of the callus and deposition of calcium in the evolutionary tissue. The loss of strength after the twenty-first day was in accord with the histologic period of resorption preceding reorganization. The returning strength from the thirtieth to forty-fifth day coincided with the reorganization of the callus into normal bony structure.

Splint Grafts in the Treatment for Ununited Fractures.—According to Phemister,[40] ununited fractures in which there was little or no displacement or angulation of the fragments might be treated satisfactorily by the simple application to the ends of the fragments of whole thickness splint grafts or in some cases of osteoperiosteal grafts bridging the fracture line and held in position by suture of the enveloping soft parts. He considered intramedullary grafts as unsuitable in the treatment for ununited fractures, but thought that Hoglund's sliding graft might be used in fresh fractures and in cases of delayed union in which marked displacement of the fragments was an indication for operation. A broad inlay graft turned on edge and made to fill both the medullary cavity and the slot cut in the cortex afforded a suitable method of treatment for cases of nonunion of the large bones.

Fracture of the Clavicle Treated by Suspension and Traction.—From observation of sixty patients with fracture of the clavicle, de Brun [41] felt that the treatment of choice which gave the most perfect healing in the shortest time was the suspension and traction method. The shortening of the clavicle with shoulder deformity and faulty posture was negligible, and practically no after-treatment was required because early motion was practiced in all cases. The subsequent strap-

40. Phemister, D. B.: Surg., Gynec. & Obst. **52**:376, 1931.

41. de Brun, H. C. W. S.: Fracture of Clavicle Treated by Suspension and Traction, Followed by Strapping, J. A. M. A. **96**:1766 (May 23) 1931.

ping was utilized merely to remind the patient that he had had an injury to the shoulder girdle, and that some caution was still necessary.

[Ed. Note.—The editors disagree with the author's views on the treatment for fracture of the clavicle, and believe that save in exceptional cases just as good or better results can be obtained from ambulatory treatment as from recumbent treatment in traction and suspension. Nor do we believe that it is necessary to immobilize the shoulder or arm for more than a brief period. Many types of apparatus have been described that maintain reduction while allowing use of the arm. Not only our own experience, but that of students of fractures in general, warrants the statement that the common type of fracture of the clavicle is a singularly benign lesion which in a high percentage of cases recovers with complete function and slight, if any, anatomic deformity and in an unusually short period of time.]

Compression Fractures of the Spine.—Watson-Jones [42] recorded seven cases of compression fracture of the spine treated by manipulative reduction. One patient died four weeks later of uremia. In the other six, treated within a few days of the injury, successful reduction was obtained. To accomplish reduction the author suspended the body of the patient face downward between two tables, the proximal portion of the thighs resting on the edge of one table and the shoulders supported by the arms on the edge of the second table, which was on a higher plane than the first table. No anesthetic was given, and immediately the patient was in position a plaster of paris jacket was applied. The patient was permitted to walk at the end of ten days, and wore the plaster for four months. Of the six patients, four had resumed their normal occupations, one was still under treatment and the other had recovered from his spinal column injury, but was invalided on account of bilateral fracture of the tarsus.

Kümmell's Disease.—From personal observations and roentgen studies, O'Brien [43] concluded that Kümmell's disease was simply an unrecognized fracture of the spine. He advised reexamination of injured spines at a later period even when the original roentgenograms had been negative, since in certain instances a second set of films revealed a fracture with characteristic change in the osseous structure.

Traumatic Separation of the Symphysis Pubis.—Sever [44] reported that he had followed three patients with fracture of the pelvis and wide separation of the symphysis pubis. Complete functional recovery

42. Watson-Jones, R.: Brit. M. J. **1**:300, 1931.

43. O'Brien, F. W.: New England J. Med. **204**:641, 1931.

44. Sever, J. W.: New England J. Med. **204**:355, 1931.

resulted in spite of failure to approximate the two parts of the pubis and persistent wide displacement. The only treatment employed in addition to rest was a tight swathe about the pelvis. From this experience the author concluded that operation to secure alinement of the pubis was rarely necessary.

Osteosynthesis in Fractures of the Hip.—Henry[45] reported the results of an investigation of proximal osteosynthesis in experimentally produced fractures of the neck of the femur in dogs after the manner of Hey Groves. The head of the femur was removed from the acetabulum, placed in apposition with the neck and fixed with a nail or screw introduced through the proximal articular surface. The hip was then replaced in the socket and the wound closed. A nail was used in three animals, but failed to hold. A rustless steel screw was then used with coarse, double pitched thread, and a slot at each end. The spongiosa was found dense enough to hold the screw only near the proximal side of the femoral head and in the trochanter or cortex of the shaft. No immobilization was used. Seven of the dogs bore weight on the hip a few days after operation. Firm bony union was demonstrated by roentgenograms forty-nine days after operation. In the earliest specimen removed ninety-two days after operation there were normal bony trabeculae and the line of osteotomy could not be seen. The cartilage over the femoral head was normal. The author felt that healing might be expected in intracapsular fractures of the hip where there were early and accurate contact of the fractured surfaces and early functional stimulation of the circulation. These experiments showed that the capital fragment devoid of all soft parts and of vascular supply united and revivified under proper physiologic conditions.

Fracture of the Tuberosities of the Tibia.—The results of a study of fifty fractures of similar type was reported by Swett, McPherson and Pike.[46] Most of these injuries resulted from automobile accidents. The authors divided the fractures of the upper end of the tibia into five groups: Group I consisted of fractures of both tuberosities; there were three cases. They were treated by manipulation; open reduction was resorted to only when good alinement could not be secured by other means. Group II was composed of fractures of the external tuberosity. These were the most common type and numbered 29. Treatment was by manipulation. Group III included fractures of the internal tuberosity, of which there were two cases. Here treatment was by manipulation with overcorrection in plaster. Group IV was composed of fractures of the tibial spine. There were ten of these cases. Treatment was

45. Henry, M. O.: J. Bone & Joint Surg. **13**:530, 1931.

46. Swett, P. B.; McPherson, S. H., and Pike, M. M.: New England J. Med. **204**:749, 1931.

by manipulation under anesthesia to secure full extension of the knee. If extension could not be obtained, either removal or suturing of the tibial spine was resorted to. Group V consisted of V-shaped fractures, of which there were 6 cases. All but one were satisfactorily reduced by manipulation. Good functional results were observed in almost all of the cases followed.

Kirschner's Wire in the Treatment for Fractures of the Lower Extremity.—Boppe [47] stated that in his opinion Kirschner's wire for securing skeletal traction in the treatment for fractures represented an important advance. He had employed the method in a number of patients with fractures, and had been impressed with the results. In fourteen patients with fractures of the lower end of the femur, the insertion of the wire had been transcondylar in twelve and through the tibial tuberosities in two. In fourteen fractures of the bones of the lower leg, he had always inserted the wire through the os calcis. The traction force used had varied from 30 pounds for the leg to from 40 to 45 pounds for the femur. The wire had been left in place until the beginning of callus formation. Active mobilization of the foot was begun in fractures of the leg after ten days, and of the knee in fractures of the femur between the twentieth and twenty-fifth days. The wire was removed after from twenty-five to forty-five days.

In the author's twenty-eight cases there were four instances in which the wire had been broken, and in one patient in whom the wire had been inserted too close to the anterior cortex of the tibia this had given way on the twenty-fifth day, but the fracture had already consolidated. Aside from the latter case, the wire had never cut through the bone, and there had been no infections. Of twenty-two fractures studied, consolidation had been obtained in a period of from forty to forty-five days for the leg and from fifty to sixty days for the femur. Anatomic reduction had been obtained in ten cases, and in eleven it had been approximative with conservation of the normal axis without angulation or with shortening of less than 1 cm.

[Ed. Note.—We share Boppe's high opinion of the efficacy and advantages of Kirschner's wire as a means of obtaining skeletal traction in the treatment for fractures and in other conditions.]

Skeletal Fixation in Difficult Fractures of the Shafts of Long Bones.—Pitkin and Blackfield [48] described a procedure of treatment for difficult fractures of the long bones, and stated that they had employed it with success in twelve cases of compound fracture of both bones of the leg.

47. Boppe: Bull. et mém. Soc. nat. de chir. **57**:10, 1931.

48. Pitkin, H. C., and Blackfield, H. M.: J. Bone & Joint Surg. **13**:589, 1931.

Four pins were introduced in the upper and lower ends of the tibia, two above and two below the level of fracture. The ends of the pins were clamped by adjustable turnbuckles. A débridement was then performed, and after the wound had been cleaned, the fracture was exposed and reduced. The apparatus was then adjusted so as to maintain proper alinement and locked. The wound was closed and a plaster casing applied, incorporating the apparatus in it but not including the foot or knee. The patient was allowed up in from three to seven days, and weight-bearing in the apparatus with the aid of crutches permitted in from seven to twenty-one days.

[Ed. Note.—We believe the method of skeletal fixation described may prove useful in certain difficult fractures. We consider it dangerous and unnecessary, however, to permit weight-bearing at the end of seven to twenty-one days regardless of how strong the method of fixation is.]

Isolated Fractures of the Tibia with Luxation of the Fibula.—Lambotte [49] called attention to fractures of the tibia accompanied by dislocation of the fibula, and said that they were probably less rare than ordinarily thought, but were commonly unrecognized. In order to be sure of diagnosing them it was necessary to make a roentgen examination of the entire segment of the limb. There were two types:

1. Isolated fracture of the tibia with dislocation of the upper end of the fibula, the equivalent in the lower leg of Monteggia's fracture of the forearm in the upper extremity. This injury was usually accompanied by a paralysis of the external popliteal nerve.

2. Isolated fracture of the tibia with dislocation of the lower end of the fibula.

Lambotte had treated patients with examples of each of these varieties of fractures. Although about fifteen instances of the first variety had been reported, the author's case seemed to have been the first of the second variety published. Both patients required open reduction.

RESEARCH

Influence of Urinary Tract Epithelium on the Formation of Bone.—Huggins [50] transplanted portions of the epithelial lining of the kidney pelvis, ureter and bladder of dogs and rabbits to various parts of the body, particularly the rectus sheath, and to synovial cavities, and found that bone associated with cyst formation was produced. The cystic

49. Lambotte, A.: Bull. et mém. Soc. nat. de chir. **57**:28, 1931.

50. Huggins, C. B.: Formation of Bone Under Influence of Epithelium of Urinary Tract, Arch. Surg. **22**:377 (March) 1931.

fluid contained a large amount of calcium and phosphorus. Bone seemed to be produced under the direct influence of the epithelial cells.

Bone was also found to form in a fascial transplant to the bladder from which the urine had been diverted, when the fascia was in close contact with the bladder epithelium.

The epithelium of the gallbladder, stomach, jejunum and prostate, when transplanted to fascia, did not lead to bone production.

Roentgen Irradiation of Bones.—In order to answer the question of whether the healing of fractures was delayed by the frequent exposures to the roentgen rays necessitated by modern methods of treatment, Schneller [51] made an investigation of the actual dosage and time of exposure in a number of patients. With about ten different exposures he estimated the maximum dosage as about 15 per cent of a skin erythema dose. He concluded that this amount of exposure could not have any effect on the formation of callus.

Shouse and his co-workers [52] exposed all of the bones of dogs to roentgen radiation, the abdominal viscera being protected by lead screens. The dosage was about three times the human epilation dose. The dogs remained in apparently normal health until eight days later, when they developed an intoxication and died within twenty-four hours. Autopsy showed extensive capillary hemorrhage of all the organs. The substance of the spleen and of the lymph nodes was reduced, and the germinal centers alone remained. The bone marrow showed only connective tissue, fat, blood vessel endothelium, phagocytic cells and occasional normoblasts. The blood showed a marked leukopenia and deficiency in platelets.

[ED. NOTE.—These two articles supplement each other; one represents a warning of what may happen with excessive roentgen radiation of the bones, while the other strikes a note of reassurance by showing that we rarely approach the danger mark in our routine examinations. That there is a danger point, however, needs to be appreciated by all.]

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51. Schneller, P.: Zentralbl. f. Chir. **57**:1414, 1930.

52. Shouse, S. S.; Warren, S. L., and Whipple, G. H.: J. Exper. Med. **53**:421, 1931.